UNIVERSITY OF OULU

FACULTY OF TECHNOLOGY

INFORMATION FLOWS IN THE FUTURE FINNISH ELECTRICITY MARKET

The changing role of households in energy transition

Saara Moisanen

ENVIRONMENTAL ENGINEERING

Master's Thesis

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TIIVISTELMÄ OPINNÄYTETYÖSTÄ Oulun yliopisto Teknillinen tiedekunta

Tutkinto-ohjelma (kandidaatintyö, diplomityö)	Pääaineopintojen ala (lisensiaatintyö)
Ympäristötekniikka (diplomityö)	
Tekijä	**Työn ohjaaja yliopistolla**
Moisanen, Saara	Prof. Eva Pongrácz, Docent, D.Sc.(Tech.), Ph.D., M.Sc. (Tech) Antonio Caló

Työn nimi
Tietovirrat Suomen tulevaisuuden sähkömarkkinoilla, kotitalouksien muuttuva rooli energiamurroksessa

Opintosuunta	Työn laji	Aika	Sivumäärä
Teollisuuden energia- ja ympäristötekniikka	Diplomityö	Helmikuu 2019	81 s.

Tiivistelmä

Globaali energiamurros vaikuttaa monin tavoin Suomen sähköverkkoon ja sähkömarkkinoihin. Yhtenä oleellisena muutoksena on hajautettuun energiantuotantoon siirtyminen ja sähköverkkoon liitetyn sähkön pientuotannon yleistyminen. Myös muut uudet energiaratkaisut, kuten kodin energianhallintajärjestelmät, yleistyvät sähkön kuluttaja-asiakkaiden keskuudessa. Samanaikaisesti sähköjärjestelmän digitalisointi muuttaa sähkömarkkinoilla hyödynnettävän kuluttajatiedon määrää, sisältöä ja hyödyntämismahdollisuuksia. Uusien energiaratkaisujen hyödyntämisen ja sähköjärjestelmän digitalisoinnin myötä tulevaisuuden kotitalouksien ja muiden sähkömarkkinaosapuolten väliset tietovirrat tulevat muuttumaan.

Tämä diplomityö visualisoi kotitalouksien ja muiden sähkömarkkinaosapuolien välisiä tietovirtoja tulevaisuuden sähkömarkkinoilla Suomessa. Visualisointi tehdään kirjallisuuskatsauksen ja energiayhtiölle toteutettavien haastattelujen perusteella. Työssä perehdytään ensin kirjallisuuskatsauksen kautta energiamurroksen tuomiin muutoksiin Suomen sähköverkkoon ja -markkinoille, sekä kotitalouksien rooliin tulevaisuudessa. Näiden muutosten tuomia mahdollisia vaikutuksia kotitalouksien tuottaman datan määrään, sisältöön ja hyödyntämiskohteisiin arvioidaan työssä kirjallisuuskatsauksen ja kokeellisen osuuden esimerkkitapausten kautta. Työn kokeellisessa osassa esitetään neljä eri esimerkkitapausta, joissa muodostettaan tietovirtakuvia kotitalouksille, jotka hyödyntävät uusia energiaratkaisuja. Havainnollistettujen tietovirtakuvien pohjalta työssä analysoidaan uusien energiaratkaisujen hyödyntämisestä aiheutuvia muutoksia markkinaosapuolten välisiin tietovirtoihin tulevaisuudessa.

Tulevaisuuden kotitaloudet Suomessa tulevat tuottamaan enemmän tietoa kuin nykypäivänä, ja tuotetun tiedon sisältö tulee olemaan laajempi kuin nykyään. Tuotetun tiedon määrän lisääntyminen ja sisällön muutos aiheuttavat tietovirtojen määrän kasvamiseen eri sähkömarkkinaosapuolien välillä. Lisäksi kotitalouksien tuottaman tiedon hyödyntämismahdollisuudet tulevat laajenemaan tulevaisuudessa.

Tämän diplomityön tuloksia voidaan soveltaa arvioitaessa energiamurroksen mahdollisia seurauksia tulevaisuuden kotitalouksien ja muiden markkinaosapuolten väliseen yhteistyöhön. Työn tuloksia voidaan myös hyödyntää vastuullisen ja läpinäkyvän liiketoiminnan luomisessa Suomen tulevaisuuden energiamarkkinoilla.

Muita tietoja

ABSTRACT
FOR THESIS

University of Oulu Faculty of Technology

Degree Programme (Bachelor's Thesis, Master's Thesis)	Major Subject (Licentiate Thesis)
Environmental Engineering (Master's Thesis)	
Author	Thesis Supervisor
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Title of Thesis

Information flows in the future Finnish electricity market, the changing role of households in energy transition

Major Subject	Type of Thesis	Submission Date	Number of Pages
Industrial Energy and Environmental Engineering	Master's Thesis	February 2019	81 p.

Abstract

Global energy transition will have many effects on Finnish electricity grid and electricity market. One of the main changes will be transformation towards more decentralized power production and the increase in the amount of small-scale on-grid solar photovoltaic (PV) systems. Other new energy solutions, like Home Energy Management Systems (HEMS), also become more common among electricity consumers. At the same time digitalization of electricity system will change the amount, content and utilization of household data and information in electricity market. Utilization of new energy solution and digitalization of the electricity system changes information flows between future households and other electricity market parties in the future.

This thesis visualizes information flows between households and other electricity market parties in the future Finnish electricity market. Illustration is made based on literature review and interviews made with case company. Thesis first provides a research about energy transition, Smart Grids and the role of households in the future Finnish electricity market in general. The effects of these changes to information flows among market parties is evaluated based on the literature review and four case studies from experimental part. Thesis provides four case studies, in which information flows related to households who utilize new energy solutions are illustrated. Based on these illustrations, thesis analyzes the changes in information flows due to the utilization of new energy solution in households in the future.

The result of this thesis is that households with new energy solutions will produce more data than currently, and the content of this data is more diverse than before. These changes cause increase in the number of information flows among market parties in the future Finnish electricity market. The content of information flows also becomes more diverse. The broadening of utilization purposes of household data will happen due to these changes.

The results of this thesis can be applied for evaluating the possible consequences of energy transition to cooperation between future households and other electricity market parties. Result of this thesis can also be utilized in creating responsible and transparent business in the future Finnish electricity market.

Additional Information

Forewords

This master's thesis was made for Partiture Oy. Research was made about information flows in the future Finnish electricity markets from the household's point of view.

I want to express my gratitude to Eva Pongrácz and Antonio Caló from University of Oulu for being my supervisors in this master's thesis project. Warm thank you for the help and guidance through this project, and also for the interesting conversations we had related to my topic. I appreciate your willingness to help me with all the challenges I faced, even though sometimes those challenges were weird or hard to explain.

Warm thank you belongs also to Jaakko Hirvensalo, CEO of Partiture, for offering me such an interesting master's thesis topic. I got the chance to deepen my knowledge about the various consequences of the energy transition. Thank you for inspiring discussions and work in Partiture. I want to thank all my colleagues for supporting and guiding me during my thesis project. Special thanks belong to Heidi Rouhiainen, who shared this journey with me and helped me whenever I needed it. I also want to thank the case company for the interviews that enabled this thesis project. Warm thank you belongs to interviewees who provided new interesting perspectives for this research.

I want to express my deepest gratitude to my friends and family who supported me during my studies and this thesis project. Special thanks belong to Tommi, who is always there for me supporting and encouraging.

Helsinki, 11.2.2019 Saara Moisanen

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ABBREVIATIONS

DSO	Distribution System Operator
ER	Electricity Retailer
GDPR	General Data Protection Regulation
HEMS	Home Energy Management System
ICT	Information and Communication Technology
MDMS	Meter Data Management System
PV	Photovoltaics
SET	Smart Energy Transition
TSO	Transmission Grid Operator

GLOSSARY

This thesis defines information flows and some of the other terms as follows:

Information flow Information flows refer to flows that consist of data and information created by households and other electricity market parties. Information flows are used for expressing the flows of this data and information between market parties. Information flows are also used for illustrating necessary business processes related to utilization of new energy solutions in households. These information flows occur between various electricity market parties.

Electricity flow Refers to the actual electricity flow in the power grid and home smart appliance.

Metering data from solar inverter Electricity generation data from prosumer's solar panels. In addition to electricity generation, this metering data includes data for example from electricity consumption, energy balance or the state of charge of possible energy storage unit.

Metering data from smart meter Data from electricity flow from and to the grid. This metering data is collected with smart meter which is located between household and power grid.

General customer information Covers customer information, address information and billing information collected from households.

Consumer Electricity end-user, who consumes energy products and services

Prosumer Electricity end-user who have additional role for electricity generation using solar PV system in addition to consuming energy products and services. This thesis excludes other than residential prosumers.

Smart meter Metering device which enables two-way exchange of electricity and information flow between household and energy providers.

Electricity Retailer (ER) Electricity market party that sells energy and other (related) services and products to consumers.

Aggregator New operator in electricity markets. Aggregators combine small-scale renewable energy production and consumption to bigger entity and use these entities for demand response activities. In other words, aggregator's role is broking energy on behalf of a group or groups of prosumers.

Distribution System Operator (DSO) Grid operators who own and manage distribution grids. DSOs' responsibilities include provision of services for secure, efficient and sustainable operation of electricity distribution systems. DSOs have legal obligation of a high quality, secure planning, operation and maintenance of the distribution grid.

Home Energy Management System (HEMS) Intelligent monitoring and controlling systems for home smart appliances. HEMS can be used to monitor and manage household's energy consumption and production, home appliances, power generation and storage devices at the consumer's side.

1 INTRODUCTION

The Finnish energy industry and ecosystem are facing a remarkable energy transition. This paradigm shift moves the entire Finnish energy ecosystem towards a more service-based industry and enables radical changes to the logic of the whole energy sector. The megatrends that influence the energy sector today can be summarized as climate change, increase the share of renewable energy sources, digitalization, global market competition and the strengthening role of customers as a more active actor in the energy ecosystem. (Energiateollisuus, 2018a) New technologies, such as Smart Grids, are expected to play a big role in future energy system in Finland. (Smart Energy Transition, 2016) Developments in ICT (Information and Communication Technology) have promoted new ICT-based energy solutions become more common in households. (Gram-Hanssen and Darby, 2018) Developments also enable new business models between customers and energy companies. (Energiateollisuus, 2018a)

Energy transition speeds up the creation of innovations for consumers. (Smart Energy Transition, 2017a) Examples of new energy solutions for consumers are solar photovoltaic (PV) systems and home automation systems. (Ministry of Economic Affairs and Employment of Finland, 2016) In Finland, the amount of household owned solar PV system has already increased rapidly over the past few years. (Energiavirasto 2018a). Small-scale solar PV systems are expected to raise significantly also in the future. (Ahonen and Ahola, 2017) Home Energy Management Systems (HEMS) are able to manage home appliances, power generation and storage devices at the consumer's side. (Eissa, 2018) HEMS also offers a tool for households to participate in demand response activities. (Beaudin and Zareipour, 2015) HEMS solutions are already available for households in Finland. (There Corporation, 2018) Smart Grids, an intelligent service platform, offer a platform for these innovations to take place. (Ministry of Economic Affairs and Employment of Finland, 2016)

Creating Smart Grids and utilizing new energy solutions such as solar PV systems require collection of electricity consumption data from electricity consumers. (Hertrampf et al., 2018) In addition to consumer's electricity consumption data, other types of data and information are needed in utilizing new energy solutions. Monitoring and controlling smart devices with HEMS for example utilize data and information about room temperature, weather and energy price forecast. (There Corporation, 2016) Smart Grids increase the amount of data collected from future households and enables new ways to utilize this data. This data collection and utilization in Smart Grids generates new information flows between households and other market parties. (Naus et al., 2014)

Information flows created by utilization of new energy solutions and Smart Grids can affect to the relationship between households and other electricity market parties. Concerns related to new energy services include the transparency of who has access to data and the freedom of choice of consumer. (Naus et al., 2014) Increased amount of household data collection and utilization may rise concerns also related to customer privacy and data protection, and therefore affect to the interest for adopting these new solutions in households. (Gram-Hanssen and Darby, 2018)

1.1 Partiture Oy

This thesis has been done in collaboration with Partiture Oy, which commissioned this research about information flows. Partiture Oy is a consulting and project management company operating in the Finnish energy sector. After its market entry in year 2013, Partiture has helped its customers to achieve their goals in their business project development and ICT-system projects. Over 2,5 million people in Finland enjoy the benefits from Partiture's projects, directly or indirectly. Consulting and project management services and new solutions in the field of clean tech form the core business of Partiture. Currently there are fifteen employees in Partiture working with various energy sector projects around Finland. (Partiture Oy, 2019)

Partiture's mission is to speed up the transformation of the companies towards more ecological and profitable business and engage consumers for the same process. Partiture helps its customers to succeed in the necessary changes that energy transition forces them to make. Partiture has an important role in various types of development projects in the energy sector. Examples of these development projects are helping Finnish Energy Retail companies and Distribution System Operators to become Datahub compliant/qualified companies through their IT-projects. Another important development of which Partiture actively takes part is bringing new energy solution more easily available for electricity consumers in Finland. (Partiture Oy, 2019)

Partiture recognizes that while energy transition takes Finland towards more sustainable future, it also tends to create complexity in the businesses of electricity markets in Finland. Understanding these changes in relationship between electricity end-user and other market parties is important in order to enable transparent and responsible business processes in the Finnish electricity market. As information flows affect the relationship between electricity end-users and other market parties, Partiture aims to investigate and understand these information flows. By understanding these information flows in the Finnish electricity market, Partiture can help tackling possible challenges related to utilizing new energy solutions in the future. (Partiture Oy, 2019)

1.2 Objectives and research questions

This master’s thesis aims to investigate information flows among future households, electricity market parties like ER and DSO and new energy solution providers. These information flows are researched based on the literature review and experimental part. Thesis then provides an analysis about the changes in information flows due to the utilization of new energy solutions in households.

Research questions of this thesis:

1. What are the most important information flows related to basic consumers?
2. What new information flows are created by the utilization of new energy solutions in households?
3. How will the information flows change between households and other electricity market parties due to the utilization of new energy solutions?

There are existing models and visualized figures about Smart Grids that consider both electrical and communicational infrastructure. (International Energy Agency, 2011) There are also visualizations which include the main devices of new energy solutions and its energy, network and data connections. (Hertrampf et al., 2018) This thesis aims to provide another type of visualization from households and other market parties. Instead of focusing the electrical or communicational structure, this thesis aims to illustrate information flows that happen between households and other market parties. These information flows are related to both household’s data and information collection and utilization processes of this data. Existing illustration types notice physical structure or technical solutions about how household data is collected or transferred. This thesis aims to provide a new way for illustrating data and information flows and utilization purposes of this data among market parties.

The expected outcome of this thesis is that utilization of new energy solutions for households will change the number and content of information flows in the future.

1.3 The scope and structure of this thesis

The thesis only considers the most relevant electricity market parties which are related to utilization of new energy solutions in households. Other possible electricity market parties which are not considered relevant for the scope of this thesis are outlined from this research.

In experimental part of this thesis, four different case studies are examined. These case studies illustrate information flows related basic consumer, prosumer with solar PV system, prosumer after Datahub and household with HEMS.

In this thesis, information flows refer to flows that consist of data and information created by households and other electricity market parties. Information flows are used for illustrating the flows of data and information between market parties. Information flows are also used for illustrating those business processes for which household data and information are utilized. These information flows then refer to necessary business processes related to utilization of new energy solutions in households. Other possible information flows are excluded from this thesis.

This thesis is divided into two parts: literature review and experimental part. Literature review provides basic information about energy transition, the changing role of households, new energy solutions available for households and information flows related to utilization of new energy solutions. Literature review also investigates the current electricity data metering and data transfer process in the Finnish electricity sector. In addition, information about how household data is currently utilized by existing electricity market parties is provided.

Experimental part introduces four different case studies from household data and information collection and utilization by various market parties. Case studies in experimental part is made based on the interviews made with case company and on literature review. These illustrations are then analyzed in order to evaluate information flow changes that are expected to happen in the future. Results of the thesis and conclusions are provided at the end of this thesis.

2 FINNISH ELECTRICITY MARKET

This chapter provides an overview about Finnish electricity market. Energy transition, the consequences of this transition to Finnish energy system and the changing role of households in Finnish electricity market are discussed. This chapter also provides basic information about Smart Grids and some of the new energy solutions that are available for households. Information flows related to utilizing new energy solutions in households are discussed as well. The role of information flows in adopting new (especially ICT-based) energy solution is discussed at the end of this chapter.

2.1 Energy transition and the changing role of households

A systematic shift towards decentralized and more sustainable energy future is often referred as energy transition. (Naus et al., 2014) The most powerful change factors which will affect to energy sector in the near future are climate change, the spread of renewable energy solutions, digitalization, international competition and the strengthening role of customers. Followed by these changes, energy sector is facing a huge energy transition in global scale. (Energiateollisuus, 2018a) Also Finland needs to prepare for energy transition. (Smart Energy Transition, 2017a) Smart Energy Transition (SET) is a research project founded by the Strategic Research Council at the Academy of Finland. SET project aims to investigate global energy transition and its effects on Finnish economy. (Smart Energy Transition, 2018) According to SET research project publication “Energiamurroksen teknologiat”, energy transition is a transition process, in which technologies and social factors interact with each other and create new opportunities for developing solutions in energy sector. (Smart Energy Transition, 2017b) In addition to renewal of existing power grids, grid operators need to prepare the energy transition and its consequences. (Fingrid Oyj, 2019a)

Energy transition will have many effects to the Finnish energy system by year 2030. Effects can be seen in specific fields, like demand response of electricity and district heating, energy efficiency of the buildings, or renewable energy production like wind power and solar energy. Changes will occur also in the field of reserve and peak power and various heat efficiency and storage options. New technologies, such as Smart Grids, are expected to play a big role in future energy system. (Smart Energy Transition, 2016)

2.1.1 Towards decentralized energy production

Over the past decades there has been systematic shift from centralized fossil fuel-based energy production towards a decentralized, low-carbon energy production. (Naus et al., 2014) This change can be seen also in Finland, where for example the amount of small-scale decentralized electricity production with solar PV system is increasing rapidly. (Energiavirasto, 2018a) Decentralization of the power system can be achieved by integrating more of small-scale renewable energy production to the grid. Large-scale power plants will still be operating alongside with decentralized systems. (Smart Energy Transition, 2016) Figure 1 illustrates the process of the development of power grid towards decentralized system.

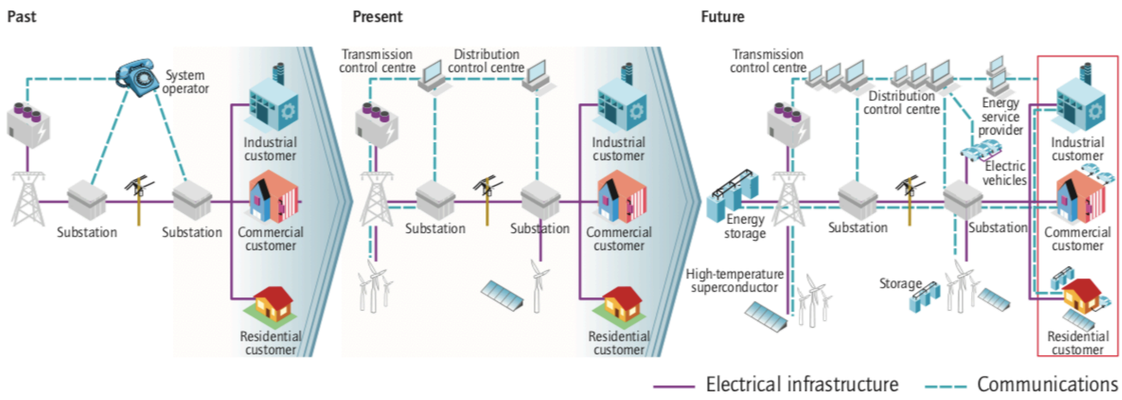

Figure 1. Illustration of the structure of energy system in the past, currently and in the future. (From International Energy Agency, 2011)

2.1.2 The role of Smart Grids in Finland

European Technology Platform SmartGrids defines Smart Grids in their publication “SmartGrids Strategic Research Agenda for 2035” (later SRA 2035) as an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to ensure an economically efficient, sustainable power system with low losses, high quality and security of supply and safety. (European Technology Platform SmartGrids, 2012)

In Ministry of Economic Affairs and Employment of Finland Smart Grid vision 2025, Smart Grids is described as a platform for changing towards more decentralized and carbon-neutral electricity grid. With Smart Grids, more small-scale renewable electricity production can be integrated to the grid in Finland. (Ministry of Economic Affairs and Employment of Finland, 2016) Ministry also defines Smart Grid as a functional entity that monitor and optimize the balance of the electricity grid, offer customers a chance to be more active part of the energy market, and serve as a platform for innovative businesses related to electricity sector. (Ministry of Economic Affairs and Employment of Finland, 2018a) Smart Grids are expected to increase the opportunities for customers to participate electricity market, increase the security of supply and create new business opportunities in an economically efficient way. Smart Grid vision 2025 offers a vision of Smart Grids in Finland in year 2035 and a roadmap 2025 which discusses about the ways to achieve this vision. (Ministry of Economic Affairs and Employment of Finland, 2016)

Change from the current electricity grid to Smart Grids require cooperation between various stakeholders. SRA 2035 defines the most important stakeholders for Smart Grids. (European Technology Platform SmartGrids, 2012) Some of the most relevant stakeholders for the scope of this thesis are mentioned in table 1.

Stakeholder	**Main roles**
Consumers	Consumption of energy products and services
Prosumer	Consumers with the additional role of self-provided (owned) electricity generation
Energy Retailer	Practice electricity retail selling and other energy service selling
Aggregator	Broking energy on behalf of a group or groups of prosumers
Energy Service Companies	Providing of a broad range of comprehensive energy solutions
ICT equipment and systems providers	Providing Information and Communication Technology (ICT System) products and services
Telecommunications providers	Providing telecommunication services
Data processing service providers	Data processing services, respecting consumer privacy
Energy Equipment and System Manufacturers	Providing Electric-technology products and services
Distribution System Operator (DSO)	Services for secure, efficient and sustainable operation of electricity distribution systems. Legal obligation of a high quality, secure planning, operation and maintenance of the distribution grid
Transmission System Operator (TSO)	Services for a secure, efficient and sustainable operation of transmission system. Legal obligation of a high quality, secure planning, operation and maintenance of the transmission grid
Policy Makers, Regulators	Regulating electricity market

Table 1. Smart Grids stakeholders and their roles. (based on European Technology Platform SmartGrids, 2012)

2.1.3 The changes in the role of consumers

Technological transition in the scope of energy transition is defined as a process, in which innovations for energy production, storage, distribution, monitoring and utilization are combined to create new solutions. These solutions are kept as change factors when they challenge or even displace existing systems, practices or individual operators. (Smart Energy Transition, 2017b) Energy transition speeds up the creation of innovations offered for consumers, which makes it possible for consumers to participate more actively on energy system. As energy transition shapes Finnish energy sector towards more service-based industry, there will be more services available for consumers to utilize. (Smart Energy Transition, 2017a)

Ministry of Economic Affairs and Employment of Finland declares in its Smart Grid vision 2025 (2016) the changes that future Smart Grids needs to prepare. These changes include the increase in the amount of PV systems in residential real estate during years 2019 to 2024. At the same time, transition to Datahub will renew information exchange in the Finnish electricity network. (Fingrid Oyj, 2019b) The concept of smart homes and home automation will also become more common, new metering solutions will be implemented and the role of demand response will increase. (Ministry of Economic Affairs and Employment of Finland, 2016) Figure 2 shows these and other possible changes that needs to be prepared by the future Smart Grids.

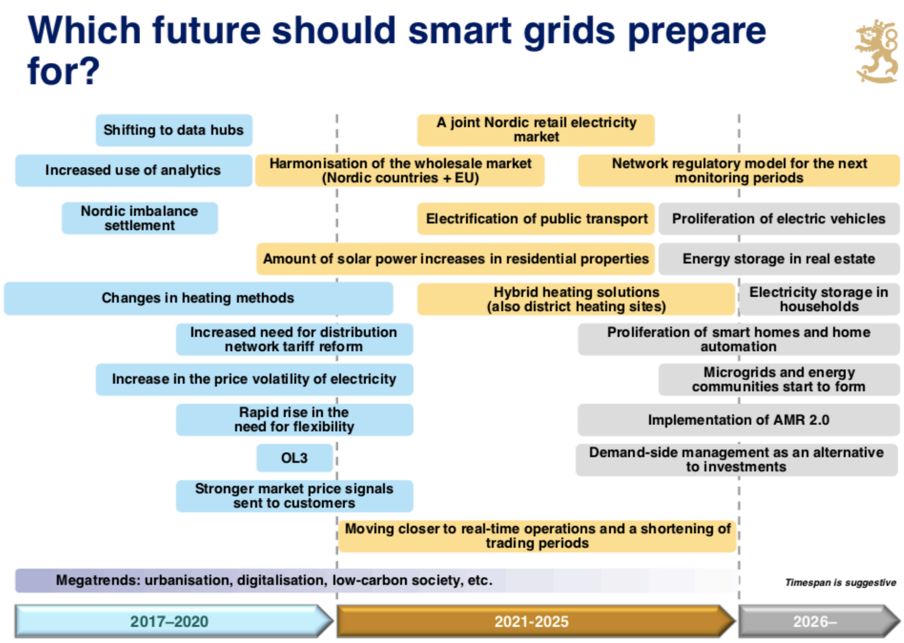

Figure 2. Possible changes that needs to be prepared by the future Smart Grids. (from Ministry of Economic Affairs and Employment of Finland, 2016)

Smart Grids offer a platform for these changes to happen. Smart Grids enable new products and pricing models, which can boost customers, communities and companies to be more active on energy market. Customers have more opportunities to make value-based choices related to their electricity consumption and production. (Ministry of Economic Affairs and Employment of Finland, 2016)

Smart Grids also benefit the exiting operators in the electricity grid. (Ministry of Economic Affairs and Employment of Finland, 2016) One of the key components of Smart Grids are smart meters, which enable two-way exchange of energy and information flows between households and energy providers. (Naus et al., 2014) When smart meters enable real-time consumption and production data measurement from the grid, grid operators can improve security in electricity supply and manage power balance more efficiently. Smart Grids offer tools for management of energy balance, power grid disturbances, and power quality. Grid operators are then capable to practice more efficient demand response and utilization of the electricity grid. New business models and connections between the electricity grid and other energy systems like heating system or infrastructures like smart cities are possible with Smart Grids. (Ministry of Economic Affairs and Employment of Finland, 2016)

2.2 New energy solutions in the future

There will be many new energy solutions available for future households. (Ministry of Economic Affairs and Employment of Finland, 2016) Basic information about some of these solutions is provided below.

2.2.1 Solar PV system

Solar PV system is a combination of devices which converts solar radiation into electricity and manage the produced electricity. The main component of the system, PV panel, is responsible for converting sunlight into electricity, while other devices in the system take care of transferring and managing the produced electricity. PV systems are modular, which enables the creation of various size power systems. PV systems can therefore be designed to fulfil various requirements. (Kalogirou, 2014)

Typical solar PV system located in household

Main solar PV system components and system's connection to household and the power grid are shown in Figure 3. The main unit is solar PV panel which produces electricity from the sun radiation. All the other equipment in solar PV system excluding PV panels can be called as Balance of System (BOS). Produced electricity can be utilized in home electrical equipment or transferred to the power grid. (Kalogirou, 2014)

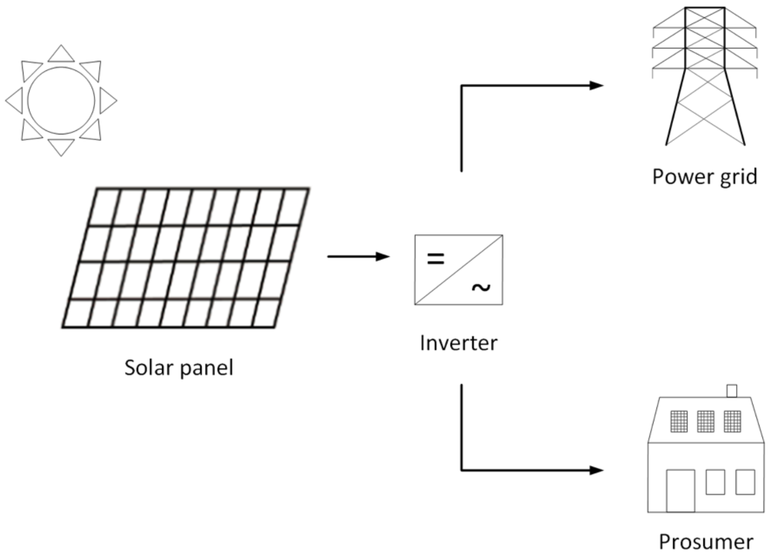

Figure 3. Photovoltaic system installation. (based on Kalogirou, 2014)

The main units of solar PV system are solar PV panels. Panels include smaller components, solar cells, which convert sun radiation into electricity. Cells are most often grouped into modules to create higher electrical output. One solar panel can include several modules. Solar cells consist of various layers of semiconducting material, which is usually silicon. When sunlight hits the panel, silicon is exposed to the solar energy. This absorption of solar energy (photon) into semiconducting material generates electrical current. Current produced is direct current, which can be conducted forward in the PV system. (Kalogirou, 2014)

As electricity produced in PV panels is direct current, it must be converted into alternating current before usage in household devices or transferring it to the grid. The device to carry out the conversion is called inverter. Inverters also manage the voltage to keep it constantly in a required level. (Kalogirou, 2014) Inverters have already been remarkably developed for example in the field of efficiency and costs of the device. New developments related to inverters are estimated to focus on integrating inverters to energy storages and control management systems of electric devices. With these solutions, household could increase the utilization rate of their own electricity produced by PV system. There are inverters that are able measure the electricity production straight from PV panels, and combined with smart meters, the electricity usage of household could be measured in real time. (Ahonen and Ahola, 2017)

PV panels can be placed into the ground or a building roof. It is favorable to locate building-integrated photovoltaics at the roofs for several reasons. Roofs normally offer unshaded access to solar radiation and possibility for optimal placement and orientation of the panel. It is also cost-effective compared to other option because of the savings in support frame costs. (Kalogirou, 2014) Support frames are used for installing the PV system on households' rooftops or even walls and balcony railings. Connectors and cables are also needed in connecting the PV system to the grid. (Ahonen and Ahola, 2017)

Prosumers in the Finnish electricity grid

As mentioned earlier in this chapter, Finnish energy system will become more decentralized, and the amount of small-scale energy production will increase. The amount of solar PV systems in households in Finland is already rapidly increasing. (Energiavirasto, 2018a)

Solar PV systems can be installed and connected to the grid (on-grid system), but there are also systems which can be used without connection to the grid (off-grid system). In Finland, the focus was long time only in off-grid solutions, which are largely utilized for example in summer cottages. Estimated capacity of off-grid PV systems in Finland is around 10 Mega-Watts (MW). After year 2010, the amount of on-grid PV systems started to increase. (Ahola, 2017) Currently the amount of on-grid PV systems increases rapidly every year, which can be seen from the 2,5-fold PV system capacity increase during year 2017. The total on-grid PV system capacity in Finland in year 2017 was 70 MW, of which the share of small-scale PV systems (smaller than 1 MW) was 66 MW. It is estimated that the capacity will increase over 100 MW during the year 2018. (Energiavirasto, 2018a)

In comparison to global on-grid PV system capacity, the amount of PV system capacity in Finland is still very small. The total global installed capacity of PV systems was at least 402,5 Giga-Watts (GW) at the end of 2017. China was the leading country with the solar PV system cumulative capacity of 131 GW installed and connected to the grid at the end of the year 2017. Other countries with the highest capacities were USA (51 GW), Japan (49 GW) and Germany (49 GW). (International Energy Agency, 2018)

2.2.2 HEMS and demand response solutions

Home energy management systems (HEMS) can be used to monitor and manage household's energy consumption and production. HEMSs are able to manage home appliances, power generation and storage devices at the consumer's side. (Eissa, 2018) HEMS also offers a tool for households to participate in demand response activities. (Beaudin and Zareipour, 2015) For example households who have solar PV system have possibilities to utilize their electricity loads in demand response activities by using HEMS. (Eissa, 2018)

There Corporation offers HEMS solution, that can be used for controlling the direct electricity heating equipment of households. ThereGate device and related cloud service enable monitoring and controlling electricity loads of household and also participation on demand response actions. (There Corporation, 2016) There are also other similar solutions that are already available for electricity end-users. Cozify offers home automation solution which allows households to manage and control all their electric devices and therefore energy consumption with one online application. (Cozify Oy, 2018) CleBox is another solution that enable control of various electrical heating elements in household, like heat pumps, and also other electric devices of households through online application. CleBox enables customers to utilize electricity when it is cheap and guide customers to decrease their electricity consumption during peak times. (Cleworks Oy, 2018)

New demand response services and aggregators

Demand response refers to lowering energy consumption during demand peaks or shifting the demand with respect to wholesale electricity prices. (Ponnaganti et al., 2017) Demand response is also defined as changing the momentary consumption of energy to help maintaining the balance between power production and consumption. The need for demand response increases when the amount of inflexible electricity production sources increases in the power grid. (Fingrid Oyj, 2019c) Variable energy production will require flexible consumption, which is why there will be need for demand response systems in the future. (Ahonen and Honkapuro, 2017) Currently demand response in Finnish electricity grid is managed by the grid operators. (Energiateollisuus, 2017)

Integrating renewable energy sources and demand response activities is one of the challenges of recent times. (Ponnaganti et al., 2017) Aggregators are new operators in electricity market, who combine small-scale renewable energy production and consumption to bigger entity and use these entities for demand response activities. (Fingrid Oyj, 2019c) Aggregators offer opportunities to households to participate demand response activities with their electricity production and storage systems. (Ministry of Economic Affairs and Employment of Finland, 2018b) In the future, individual aggregators can sell demand response to TSO, DSOs and deregulated market participants. (Ikäheimo et al., 2010)

Prosumer's electricity production can be used for demand response activities if it is capable to react the market situations and it can be used to lower the household's electricity usage from the grid. Development of hour-based electricity data metering and building automation systems support the development of demand response systems. (Smart Energy Transition, 2017a) Remote meter reading makes it easier for distribution companies to track instant and peak consumption and perform demand response easier and reliable. (Kabalcia and Kabalcib, 2018) Using individual contributions in the prevention of peak loads would only be possible with the help of detailed monitoring data from the Smart Grid. (Naus et al., 2014)

The final report of Smart Energy Transition project's and Sitra's Energiamurrosareena-project argue that more electricity end-users should be integrated to demand response activities in Finland. (Smart Energy Transition, 2017a) Aggregators will be new market parties in Finland, as currently there are no existing aggregators operating in Finnish electricity grid. There are two on-going aggregator pilot projects which are implemented by Fingrid and made in cooperation with Helen Oy and Voltalis S.A. These pilot projects aim to find solutions for challenges that individual aggregators need to tackle. These challenges include for example information exchange between market parties and requirements for developing ICT-systems. (Fingrid Oyj, 2018a)

2.3 Information flows related to utilization of new energy solutions

The term information flows can be defined as a sociological concept which refers to diverse forms of data, information and knowledge exchange between actors in the energy grid. As a result of utilizing new ICT-based services and products, new information flows between households and energy service providers are formed. (Naus et al., 2014) In this thesis, information flows consist of data and information created by households and other market parties. Information flows in this thesis refer either to actual data or information exchange flow or necessary business processes flows that utilize household's data or information. These information flows occur between various electricity market parties.

The increase in the amount and content of data collected from future households enables developing new services for households. (Fortum Corporation, 2017) Currently, data measured from households includes metering data from electricity flows between household and the power grid. This data is collected with smart meters. (Energiateollisuus, 2016) New ICT-based energy solution provide new sources of electricity data from households. For example, solar PV systems produce electricity generation data which is collected by solar inverter. (Hertrampf et al., 2018) If solar PV system is integrated to energy storage, data from the charge balance of the energy storage is produced as well. (Fronius International, 2019) Home automation systems provide new data about electricity loads of smart home appliances. Data from electricity loads of home electric appliances, like washing machine, dryer, dishwasher, lighting and computers can be monitored with home automation system and controlled remotely. (Matallanas et al., 2012)

In addition to electricity data, these smart homes which utilize new ICT-based energy solutions produce other types of data sources. In addition to household's electricity loads, some HEMSs are capable of collecting and utilizing data about room temperature, weather information and parameters set for the load controls for example. HEMS then utilize both household data and data produced from outside of home (like weather information) in home energy management tasks. (There Corporation, 2016) Participation for demand response actions requires also collection and utilization of large amount of both household data and outside data. (Naus et al., 2014)

Digitalization of electricity grid promote arrival of new ICT-based services and products in Finnish electricity sector. (Smart Energy Transition, 2018a) Smart homes then can be seen as a flexibly-connected and interacting element of energy system, equipped with ICT that can be monitored and controlled remotely. (Gram-Hanssen and Darby, 2018) Developments in ICT promote new ICT-based energy solutions become more common in households. (Gram-Hanssen and Darby, 2018) Digital solutions and data collection tools are needed to custom new energy services for customers' needs. Tomorrow's service providers will need in-depth customer insight and a large amount of customer data to develop their services. (Fortum Corporation, 2017) This data is produced by households who utilize smart energy solutions. (Hertrampf et al., 2018) With new energy services households become more connected to network operations. Future grids will then rely more on interactions between distributed actors. (Darby, 2018)

2.4 The role of information flows in adopting new energy solutions

Information has an important role in redefining the relationships between households and energy providers. (Naus et al., 2014) Smart homes that utilize new ICT application are not seen only as a site for resource flows like electricity, heat and information, but also a site with external control of these flows. This is especially the case in demand response activities. User of smart appliance (smart home owner) can be seen as a user of electricity system to gain benefits from demand response. But on the other hand, network operator 'use' the building and its occupants in system management activities. The term "user" has then a new meaning in the future. (Darby, 2018)

2.4.1 Transparency

One of the main concerns related to new energy services include the transparency of who has access to data and the freedom of choice. The set-up in which control of the electricity usage of households comes from outside of home may be resisted as it can be seen as transferring the power of control from households to the energy companies. Occupants of households want to maintain their freedom to choose when they use electricity and for what purposes. (Naus et al., 2014) An external control and utilization of households' smart appliances may rise concerns related to power of control of homes. (Darby, 2018) One way for energy companies and other market parties for keeping good relationship with household is to allow the customer to have the final word. This means for example providing customers possibility to not to answer the load control commands of the service provider. (Ikäheimo et al., 2010)

2.4.2 Data security and privacy

Adopting smart technology requires open data flows between homes and outside world. Home is seen as a secure place, but new data flows force consumers to rethink if they trust their technology and energy providers. The concept of security then plays an important role related to new smart home technology. (Gram-Hanssen and Darby, 2018) It is claimed that the potential loss of privacy and alienation of the consumer are challenges that adoption of new energy solution will have to solve. (Parag and Butbul,

2018) Privacy concerns have already limited the interest for adopting these new solutions in households. (Gram-Hanssen and Darby, 2018)

There are examples on how privacy and data security aspects have been affecting the implementation of new smart technology. A survey from Austria revealed that households have concerns about privacy and security issues, even though they would trust their energy supplies. (Gram-Hanssen and Darby, 2018) The process of implementing smart meters in the Netherlands showed an example of how data privacy issues are related to implementation of smart meters in households. In the Netherlands, several civil society organizations and members of parliament expressed their concerns related to consumer privacy and security, which delayed the roll-out of smart meters in households. One of the main concerns was the mandatory acceptance of smart meter, while knowing its vulnerability to cyber-crime. (Naus et al., 2014) TÜV Rheinland's experts from Germany showed an example of how easily data security of solar inverter can be broken down. After breaking the data security, hackers can cause damage for example to energy storage systems or even paralyze the power grid. (Kortelainen, 2018)

Digitalization of energy system require development of even stronger data security. (Energiateollisuus, 2018a) European Commission recommends various data protection and privacy provisions and guidance. EU protects consumer's personal data by rules which regulate who can have access personal data and under what circumstances. (European Commission, 2019) Smart Grid Information security report is an example of how EU aims to protect data privacy and security related to Smart Grids and new technology. In this report it is argued that utilizing new technologies together with consumer privacy orientated product and service development is important. This report considers also EU General Data Protection Regulation (GDPR) and its effects to Smart Grids Standards. (CEN-CENELEC-ETSI Smart Grid Coordination Group, 2014) Regulations and recommendations for data security are also given in national regulation in Finland. For example, metering decree (66/2009) set requirements for data protection of the metering equipment. Energiateollisuus describes in its document "Principles of hourly metering 2016" the responsibilities of various market parties related to data security and data privacy management in electricity data metering. (Energiateollisuus, 2016)

3 ELECTRICITY DATA METERING AND DATA TRANSFER IN FINLAND

This chapter provides the basic information about the current Finnish electricity network, grid operators and current electricity data metering and transfer chain. Regulations related to electricity data management in both the European Union and Finland are discussed. The role of various grid operators and market parties in electricity data metering and transfer is provided. This chapter also provides an overview of Datahub and its effects to data transfer chain in Finland.

3.1 Finnish electricity system

The electricity system in Finland consist of power plants, transmission grid, regional networks, distribution networks and electricity consumers. Finnish electricity system is part of the inter-Nordic power system, which includes also power systems from Sweden, Norway, and Eastern Denmark. Finnish power system has grid connections to the power systems in Russia, Estonia, and Continental Europe. (Fingrid Oyj, 2019d)

3.1.1 Electricity production and consumption in Finland

Electricity consumed in Finland consists of both produced and imported electricity. The total amount of electricity consumed in Finland in year 2017 was 85,4 Terawatt hours (TWh). Electricity was produced of the amount of 65,0 TWh, which covers 76,1% of total electricity consumption. The share of imported electricity was then 25,4 TWh, which covers 23,9 % of total electricity consumption. Figure 4 shows the electricity consumption in Finland by source in year 2017. (Energiateollisuus, 2018b)

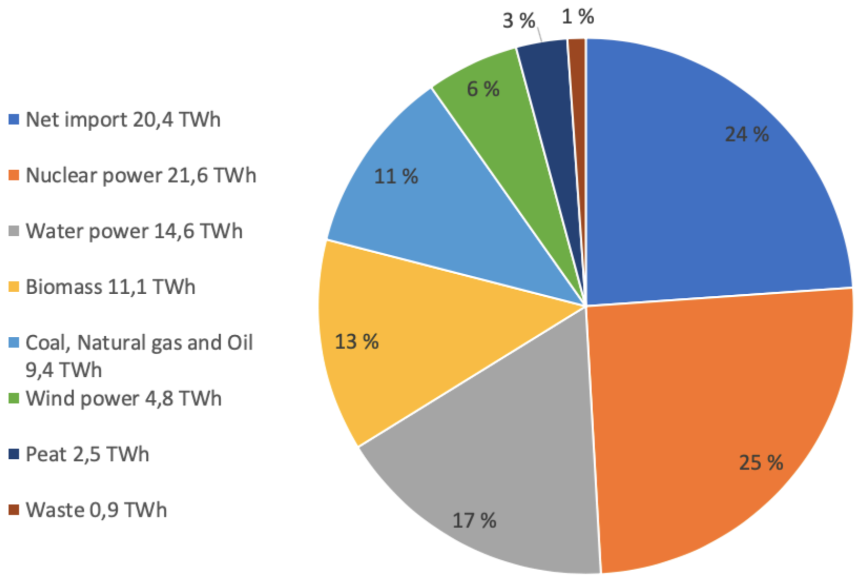

Figure 4. Electricity consumption by source in Finland in year 2017, in total 85,4 TWh. (based on Energiateollisuus, 2018b)

Electricity produced in year 2017 was 65,0 TWh. Electricity was mainly produced from renewable energy sources, as its share of total electricity production was 47%. Electricity production in Finland leans also strongly on nuclear power. The share of electricity produced by nuclear power was 33,2% which makes it the biggest single electricity production method. Fossil fuels covered 14,6% and peat 4,1% of the total electricity production. (Energiateollisuus, 2018b) Electricity production by sources in Finland is shown in Figure 5.

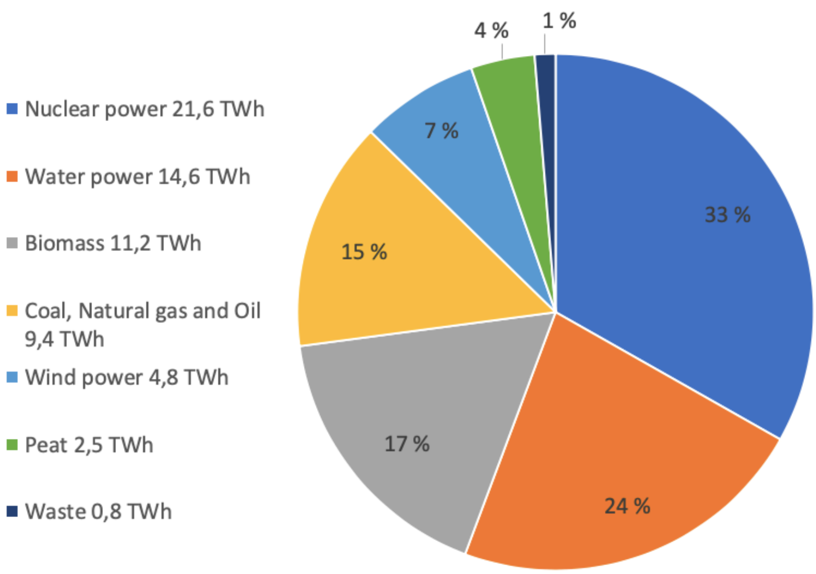

Figure 5. Electricity production by source in Finland in year 2017, in total 65,0 TWh. (based on Energiateollisuus, 2018b)

3.1.2 Electricity retail market

Retail sales of electricity refers to selling electricity to electricity end-users. Electricity Retailers (ERs) are the entities who practice electricity retail selling. (Energiavirasto, 2018b) Responsibilities and obligations for Electricity Retailers are set in the Finnish legislation, for example in Electricity Market Act (588/2013) and decrees and orders issued under it. Legislation regulates the starting of electricity retail business and operations of the retailers. (Energiavirasto, 2018b) In Finland, there are 100 Electricity Retailers on the market. (Fingrid Oyj, 2019b)

3.1.3 Distribution of electricity from production to consumer

Distribution of electricity from production points to consumers is managed with national-wide power transmission grid. This grid consists of 110-400 kilovolt (kV) transmission grid, other regional grids with the size of 110kV, and smaller 0,4-70kV distribution grids. Operating in the electricity grid in Finland can only be practiced with the authorization given by the Energy Authority. (Energiavirasto, 2018c) Operators in the electricity grid in Finland have different responsibilities set by Finnish legislation. Transmission grid (110-400 kV) is operated by Fingrid Oyj. Fingrid Oyj is the only Transmission Grid Operator (TSO) in Finland, and its task is to maintain Finnish transmission grid performance. Fingrid manage the balance of production and consumption in the grid, the system security and power grid disturbances. It also ensures the maximal transmission capacity for international electricity trade. In addition, Fingrid manages the necessary information exchange between market parties in Finnish electricity market. (Fingrid Oyj, 2019e) Fingrid's power transmission network of Finland is shown in Figure 6.

Distribution grids (0,4-70kV) are owned and managed by local Distribution System Operators (DSOs). DSOs' responsibilities include maintaining and developing of the grid, connecting electricity production sites to the places of electricity usage and distribution of electricity. DSOs are also responsible of the condition of the distribution grid and ensuring an adequate power quality for consumers. (Electricity market act, 588/2013) There are 77 Distribution System Operators who operate low voltage networks in Finland. In addition, there are also 10 DSOs who operate high voltage distribution network (110 kV), and four operators of private distribution networks. (Energiavirasto, 2018c)

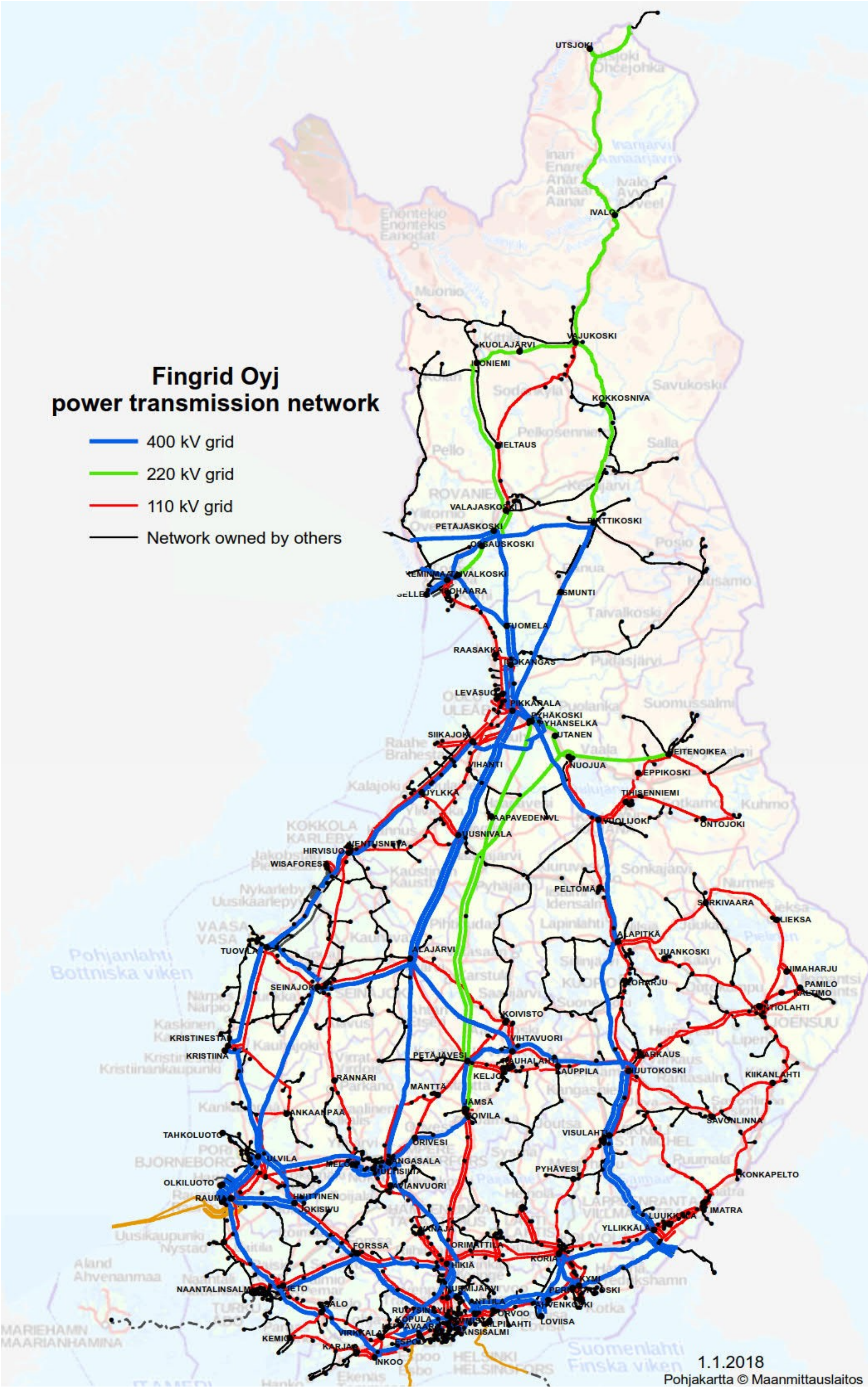

Figure 6. Fingrid’s power transmission network. (figure from Fingrid Oyj, 2018b)

3.2 Regulations for electricity data metering and transfer

Electricity data metering and transfer in Finland is regulated by various standards, acts, decrees, orders and recommendations by different stakeholders. This chapter provides information about regulations for electricity data metering and transfer.

3.2.1 *European Union Standards for Smart Grids*

Smart Grids Standards, which are common for all European Union countries, have been formed by European Standardization Organizations (ESOs), and more precisely three organizations: The European Committee for Standardization (CEN), The European Committee for Electrotechnical Standardization (CENELEC) and the European Telecommunications Standards Institute (ESTI). These three organizations formed Smart Grid Coordination Group (SG-CG) and published Smart Gris Set of Standards, which connects the various standards to their sphere of influence in Smart Grid. These standards form the basis of the Smart Grid regulation. ESOs co-operate with the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC) and International Telecommunication Union (ITU) while preparing standards for in European Union. (CEN-CENELEC, 2018) In Finland, the Electrotechnical Standardization Organization is SESKO ry. SESKO implement international electrotechnical standards in Finland and enforce them as national SFS standards. (SESKO, 2018) Figure 7 shows the fields of standardization and responsible parties.

	General	**Electro techniques**	**Telecommunications**
World	International Organization for Standardization (ISO)	International Electrotechnical Commission (IEC)	International Telecommunication Union (ITU)
Europe	The European Committee for Standardization (CEN)	The European Committee for Electrotechnical Standardization (CENELEC)	European Telecommunication Standards Institute (ETSI)
Finland	Suomen Standardoimisliitto SFS ry	Finland's National Electritechnical Standardization Organization SESKO ry	Finnish Communications Regulatory Authority

Figure 7. The fields of standardization. (based on SESKO, 2018)

The most important European Union standards related to Smart Grids are listed and connected to various use cases in document Smart Grid Set of Standards. (CEN-CENELEC, 2018) One of the Smart Grid document that is relevant for electricity data management is Smart Grid Information Security report. Smart Grid Information Security report, published by SG-CG, presents a high-level guidance of how different standards could be used and what should be considered when developing Smart Grid information security. (CEN-CENELEC-ETSI Smart Grid Coordination Group, 2014) According to Smart Grid Information Security report, there are two main sources of privacy relevant data in the future Smart Grid. These are the data generated by smart meters and data generated in the context of electric vehicle. It is also said in this report that smart homes will also generate an additional source of private data. Privacy protection is discussed in the report as a major concern. The effects of GDPR for Smart Grids Standards needs to be considered as it is the most important legislative provision with regard to data protection and privacy in Europe. GDPR needs to be taken into account when establishing and adapting technical standards for Smart Grids. (CEN-CENELEC-ETSI Smart Grid Coordination Group, 2014) European Commission also recommends various data protection and privacy provisions and guidance. EU protects consumer’s personal data by rules which regulate who can have access personal data and under what circumstances. (European Commission, 2019)

Smart Grid Information security report discusses about concerns related to data privacy of a consumer. Consumer’s power consumption data could be misused for example by burglars, criminal enterprises, law enforcement and advertising. Policies can be set to set constraints for data usage, but it is more efficient to apply policies alongside with privacy enhancing technologies. These technologies allow utilizing data for a specific purpose without the requirement for privacy critical data. Report argues that while Smart Grids is developed, utilizing privacy enhancing technologies together with consumer privacy orientated product and service development is important. (CEN-CENELEC-ETSI Smart Grid Coordination Group, 2014)

3.2.2 Regulative authorities in Finnish electricity sector

Finnish electricity market is highly regulated by acts, decrees and recommendations given by various authorities and associations. Ministry of Employment and the Economy is responsible for preparation of the legislation for electricity sector. The main regulatory body of the electricity sector is The Energy Authority (Energiavirasto), which supervises both electricity market and networks. The Finnish Competition and Consumer Authority has separate unit, which deals with some cases which are related to electricity market. (Krogerus, 2016)

Finnish energy (Energiateollisuus ry) is an association of energy sector in Finland. Finnish energy release recommendation and guidelines related to operations and information exchange of electricity retail market. The purpose of these recommendations is to standardize the practices among operators in electricity retail market. Recommendations related to hourly metering and information exchange are examples of the documents made by Finnish energy. (Energiateollisuus, 2018c)

3.2.3 Finnish regulations for electricity data metering and transfer

Legislation related to the Finnish electricity sector consists largely of Electricity Market Act (588/2013 or EMA) and valid decrees and orders which are made based on it. (Krogerus, 2016) This section discusses about the regulations which is relevant for electricity data metering and transfer.

Finnish regulations for electricity data metering and transfer include several acts, decrees and orders. Requirements are given metering for both electricity consumption and production. Finnish acts, decrees and orders which set legislative obligations for electricity data metering are listed below. In addition to requirements set in the legislation for the electricity market, Finnish energy's recommendation document Principles of hourly metering 2010 and updated Finnish version from year 2016 gives guidelines for hourly metering.

Acts:

- Electricity Market Act (Sähkömarkkinalaki 588/2013)
- Energy Efficiency Act (Energiatehokkuuslaki 1429/2014)
- Measuring Instruments Act (Mittauslaitelaki 707/2011)

Decreed and orders

- Government decree on determination of electricity supply and metering, also known as Metering decree (Valtioneuvoston asetus sähköntoimitusten selvityksestä ja mittauksesta, tunnetaan myös Mittausasetuksena 66/2009)

- Government decree on essential requirements of metering devices, demonstration of conformity and specific technical requirements (Valtioneuvoston asetus mittauslaitteiden olennaisista vaatimuksista, vaatimustenmukaisuuden osoittamisesta ja teknisistä erityisvaatimuksista 211/2012)
- Government decree on changing the decree 66/2009 (Valtioneuvoston asetus sähköntoimitusten selvityksestä ja mittauksesta annetun valtioneuvoston asetuksen muuttamisesta 217/2016)
- Decree of the Ministry of Employment and the Economy on data interchange related to the determination of electricity supply, also known as Message traffic decree (Työ- ja elinkeinoministeriön asetus sähkökaupassa ja sähköntoimitusten selvityksessä noudatettavasta tiedonvaihdosta, tunnetaan myös Sanomaliikenneasetuksena 273/2016)
- Energy Authority's regulation on itemization of bills concerning electric selling and electricity transmission (Energiaviraston määräys sähkön myyntiä ja sähkön jakelua koskevien laskujen erittelystä 1097/002/2013)

Other data metering and transfer related documents

- Principles of hourly metering 2016 & updated Finnish version from year 2016 (Tuntimittauksen periaatteita 2016)
- Message Traffic Procedural Instructions, Practical Procedural Instructions for the Electricity Market (Sähkön vähittäismarkkinoiden menettelytapa- ja sanomaliikenneohje)
- Ediel Messaging: General Application Instructions by the Finnish Energy Industries (Fingridin Ediel sanomavälityksen yleiset sovellusohjeet)

3.3 Electricity data metering and data transfer chain

This section discusses about the electricity data metering and data transfer chain in the Finnish electricity system. Legislative obligations and main requirements and responsibilities related to electricity data metering are provided. The metering infrastructure and market parties related to electricity data metering and data transfer chain are illustrated in Figure 8.

3.3.1 Legislative obligations for electricity data metering and transfer

According to the Electricity Market Act (588/2013), the system operator shall organize the metering of the electricity supplied in an appropriate manner, as balance settlement of the grid and billing are based on the metering. Act requires that the system operator need to inform the metering data related market parties. (588/2013, §22)

Energy Efficiency Act (1429/2014) sets reporting requirements for Electricity Retailer. According to act, Electricity Retailer need to provide a report to their customer about their electricity usage once in a year. Act also set requirements for the content of the report. (1429/2014)

Measuring Instruments Act (707/2011) and Government decree on essential requirements of metering devices, demonstration of conformity and specific technical requirements (211/2012) regulate the usage and characteristics of electrical energy meters. The purpose of the act and decree is to secure the reliability of operation, methods of metering and metering results of the metering instruments. (707/2011 & 211/2012)

Government decree on determination of electricity supply and metering (66/2009) and Government decree on changing the decree (217/2016) are the most important decrees related to metering. (Energiateollisuus, 2016) Metering decree repeats some of the same requirements that EMA set, and in addition gives more precise requirements for example metering equipment, meter reading system and the frequency of reading the metering data. (66/2009 & 217/2016)

Energy Authority has made an order which set on presenting of metering data on bills. This order is called Energy Authority’s regulation on itemization of bills concerning electric selling and electricity transmission (1097/002/2013). This order has to be taken account when planning of principles for hourly metering. (Energiateollisuus, 2016)

Decree of the Ministry of Employment and the Economy on data interchange related to the determination of electricity supply (273/2016) set requirements for data interchange in electricity supply. Decree set the timeframes to the system operator for providing metering data for relevant market participants. (273/2016) Further information and guidelines for message traffic between market participants are discussed in Message Traffic Procedural Instructions, Practical Procedural Instructions for the Electricity

Market and in Ediel Messaging: General Application Instructions by the Finnish Energy Industries.

3.3.2 Responsibilities in electricity data metering and information exchange

According to the legislation on the electricity market, it is the Distribution System Operator's responsibility to arrange electricity consumption metering in Finland. Responsibility includes arranging the metering, reading the metering data, detection of the accuracy, transmission and reporting of metering data. DSO can organize the meter reading by itself or externalize it. Responsibility to organize metering stays on DSO even in the case of externalization. Transferring the metering data to other market parties, like Electricity Retailer, is DSO's responsibility. (Energiateollisuus, 2016)

Electricity Retailer's (ER's) responsibilities include mainly receiving the metering data and using it for billing activities. Another responsibility of electricity retailer is to provide DSO information that is relevant for metering procedures. This information, among general information of the customer, means for example changes in electricity contracts, like starting or ending date of the contract. ER is also obliged to provide a report of electricity usage to their customers once in a year. (Energiateollisuus, 2016)

Both ER and DSO need to be able to manage information exchange according to Finnish legislations and message traffic procedural instructions. In Finland, the correct information exchange in electricity market and balance settlement is organized with PRODAT and APERAK messages. (Fingrid Oyj, 2018d) DSO is responsible for accuracy of information, but ER is obliged to inform DSO if noticing any faults in messages. (Energiateollisuus, 2016)

Electricity consumer is responsible of its own electrical devices and keeping them on required condition. Consumer's low-voltage switchboard for example needs to be in a proper condition for metering activities. If consumer and DSO have agreed in load management activities, consumer is responsible for related connections and wiring of the low-voltage switchboard. DSO manages the connections of the meter, but if consumer and DSO have agreed in load management activities, consumer is responsible for ensuring correct adjustments to its low-voltage switchboard. If consumer wants to connect its own electricity production to the grid, consumer is responsible of informing the DSO and making a production contract with the operator. (Energiateollisuus, 2016)

3.3.3 Main requirements for electricity data metering, data transfer and metering infrastructure

Requirements of the DSO's electronic metering system and the system for data management are set in metering decree. Requirements include features like remote reading facility, ability to receive load control commands via the data network, data registering and storing in MDMS and data protection of the metering equipment. In addition, DSO is required to give hourly-metering equipment to customer on request. This metering equipment shall include a standardized connection for real time monitoring of electricity consumption. (66/2009)

Metering infrastructure for measuring, reading and storing data consists of metering equipment, Meter Data Reading System and Meter Data Management System (MDMS). This infrastructure is illustrated in Figure 8 later in this section. Smart meters measure selected quantity and store the data in regular intervals. Electricity data measured from meters include electricity flow and certain qualities of electricity, like power quality and outage information. (Energiateollisuus, 2016)

According to metering decree, hourly metering equipment is defined as equipment or combination of equipment that meters and registers the bidirectional electricity flow from and to the grid on an hourly basis. Metering data is stored into the memory of the equipment, and from there memory data can be read via data transfer network. (66/2009) Hourly metering is defined as electricity metering implemented at hourly intervals and registration of this measured data to the memory of the metering equipment. (66/2009) Metering of the electricity data must be based on hourly metering and remote meter reading. Based on the metering decree, DSO needs to organize hourly metering for at least 80% of all metering points. (66/2009) Those metering points that do not have to include hourly metering, are metering points which are smaller than 3x25A and metering point with annual usage is a maximum of 500 Kilo-Watt-hour. Requirements for metering points outside of hourly metering are also set in the metering decree. (66/2009)

Data transmission must allow two-way information exchange, and data transmission should be possible at all times of day and night. Data can be sent from meter device to meter reading system automatically and reading the data must not destroy or alter the metering data. Reading system must read the metering data from metering device at least once every 24 hours. Reading system transfers the data from meter to MDMS, which is

DSO's official meter data storage system. Data is managed in MDMS, and after that it is ready to be transferred to the market parties. (Energiateollisuus, 2016)

Electricity data metering and transfer chain

The metering infrastructure and market parties related to electricity data metering and data transfer chain are shown in Figure 8. Figure is made based on regulations discussed above. Figure 8 is a simplified version of the electricity data metering and data transfer chain which was shown in the original reference.

Electricity data metering starts with the hourly metering equipment. This kind of two-way electricity flow metering is required in Finnish regulations for electricity sector. Metering data is read remotely from the meter and transmitted to the MDMS. MDMS manages the data, and after that data is ready to be transferred by DSO to other market parties. (Energiateollisuus, 2016)

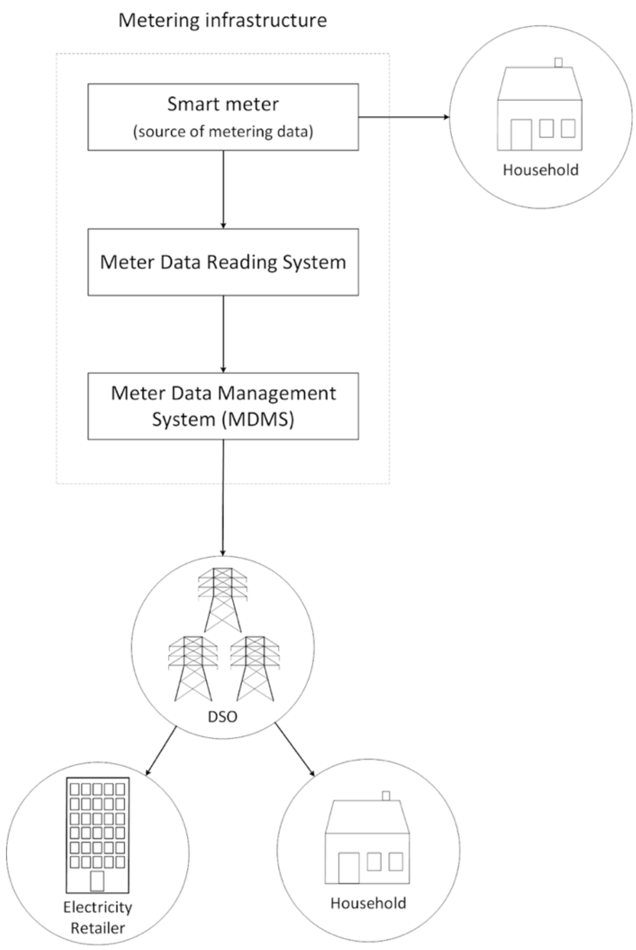

Figure 8. Electricity data metering and data transfer chain. (Figure adapted from Figure 2 in reference Energiateollisuus, 2016)

3.3.4 Consumer's access to metering data from smart meter

Consumer's hourly metering data needs to be provided to the consumer at the latest at same time as DSO provides the data to ER. This means that the data needs to be available in day after electricity usage at 11am at the latest. In Finland, the main way to provide metering data for consumers is via web-based Online services offered by DSO. (Energiateollisuus, 2016) Consumers can also require DSO to provide hourly metering devices which include standardized interface for monitoring real-time electricity consumption. These metering devices are required to include standardized interface to enable real-time tracking of electricity consumption. (66/2009) According to Energy Efficiency Act, ERs are required to send their customers a report of their energy usage once in a year. Figure 9 illustrates the disclosure of metering data from smart meter to consumer.

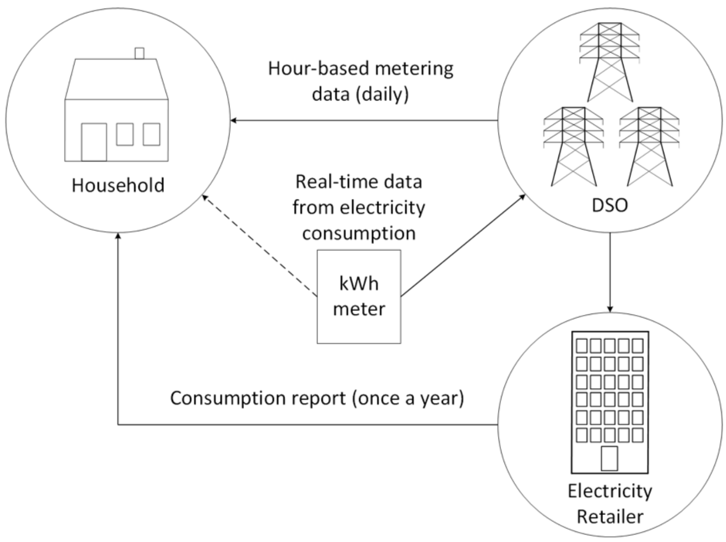

Figure 9. The disclosure of the metering data from smart meter to consumer. (Figure adapted from Figure 6 in reference Energiateollisuus, 2016)

3.3.5 Responsibilities in data security and privacy management in electricity data metering and transfer

Principles of hourly metering 2016 describes the responsibilities of various market parties related to data security and data privacy management in electricity data metering. DSO is responsible for protection of metering data during data metering, saving and transferring processes. Hourly data have to be managed as similar protection as personal information, starting already from the metering devices. Consumer or prosumer and a third party authorized by them, have access to their metering data. Among consumer or prosumer and third party authorized by them, metering data is also released to other electricity market participants (like Electricity Retailers) who need the data for example billing. (Energiateollisuus, 2016) DSO have to ensure that information security in remote meter data reading system is comprehensively ensured. Well-known data transmission protocol has to be applied in data transmission. Access to data must be prevented from unauthorized persons. If DSO purchase meter reading as a service, ensuring information security and responsibilities related to it need to be agreed in the service contracts. (Energiateollisuus, 2016)

3.4 Datahub and its effects to data transfer chain

Currently electricity market parties manage data exchange bilaterally, which means that the information exchange is decentralized and complex. (Fingrid Oyj, 2019b) Figure 10 illustrates current data transfer chain between market parties.

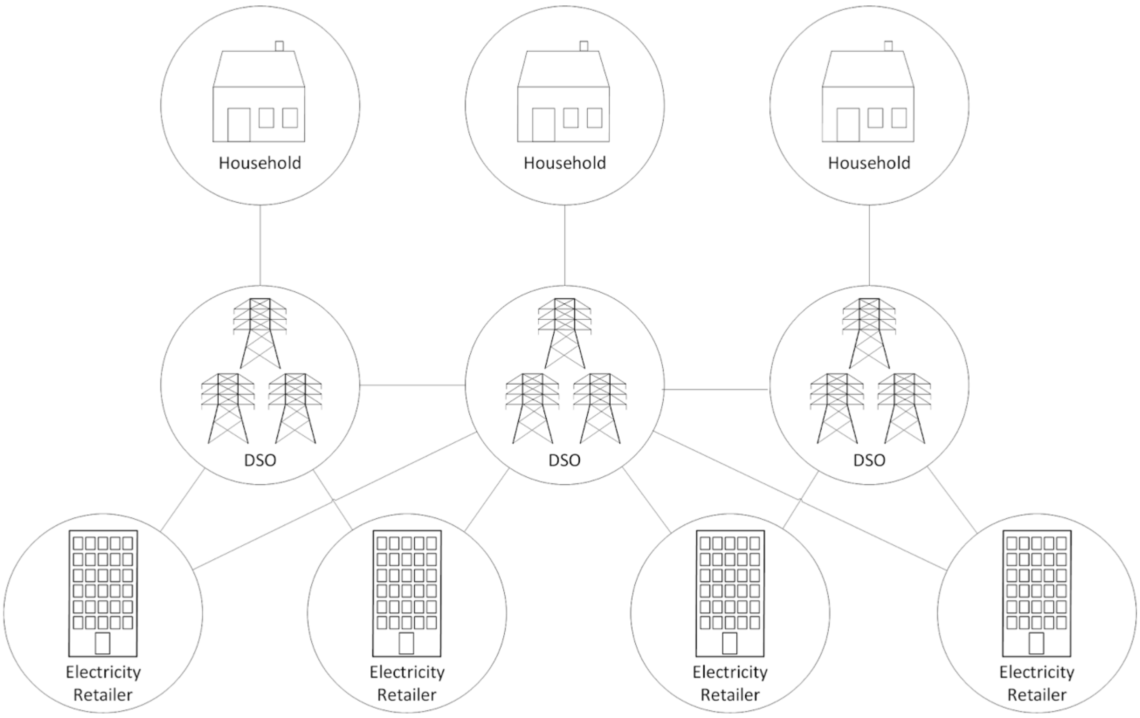

Figure 10. Current upper level data transfer chain between market parties. (Based on Fingrid Oyj, 2019b)

Datahub, a new centralized data exchange system for Finnish electricity retail market will be implemented by Fingrid Oyj by 2021. (Fingrid Oyj, 2019f) The idea of Datahub is to speed up, simplify, and improve the processes for every market party by offering a solution for centralized data exchange (see Figure 11). Datahub will be a metering data, customer information, and electricity metering point information storage, to which market parties can transfer and ask the data needed for business processes in electricity market. The big change that Datahub brings to Finnish electricity market is that the communication related to market processes will in the future happen only with Datahub instead of bilateral communications between market parties. After implementation of Datahub, information exchange between market parties is practiced by centralized and standardized methods. Datahub enable more efficient monitoring of practices that are not in accordance with the recommendations and guidelines set for the industry. (Fingrid Oyj, 2019b) Figure 11 illustrates the future centralized data transfer solution when Datahub is in use.

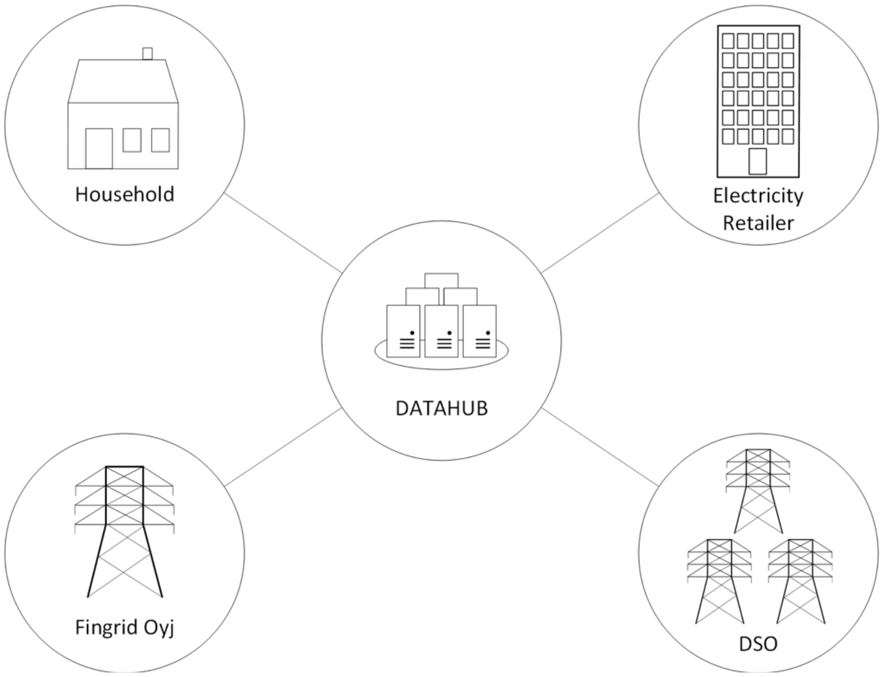

Figure 11. Future centralized data transfer solution when Datahub is in use. (Based on Fingrid Oyj, 2019b)

3.4.1 Business processes in Datahub environment

Datahub will be mandatory data exchange solution for all electricity market parties. DSOs and ERs in Finland will utilize Datahub for their data exchange. Also, Fingrid Oyj uses Datahub for its processes. Possible third parties operating in Finnish electricity sector will also use Datahub for data exchange. To electricity customers, Datahub assure an efficient and clear services, but the system itself does not really show in customers daily life expect improvements in customer service and faster processing time of contracts. (Fingrid Oyj, 2019b)

The main responsibility of ERs in Datahub is starting processes related to contracts and keeping the customer information updated. These processes include for example setting new contract when customer is moving or changing electricity supplier. Datahub also gives ERs access to information which will help it to serve their customer better in customer service situations. This includes for example information about metering points, electricity transfer products and metering data of customer. (Fingrid Oyj, 2018c)

One of the main tasks of DSO is to deliver metering data daily to Datahub. Yesterday's metering data needs to be transferred to Datahub during current day at 23.59 at latest. This data is then provided to market parties who are entitled to it. Responsibility of metering data validation stays at DSO. Maintaining the metering point information, electricity distribution contract information and electricity transfer product information are DSOs' main tasks in Datahub. There are some possible occasions in the future when DSO needs to communicate straight with ER, but these situations will occur rarer that currently. (Fingrid Oyj, 2018c)

Metering data exchange will improve the processes of DSO, especially in situations when DSO needs to provide customer's metering data to third party or managing the authorizations of these third parties given by customer. This way DSO does not need to agree about metering data exchange separately between every market party. Also new online service, offered by Datahub, will cover the legislative responsibility to report metering data to customer. This responsibility belongs currently to DSO. (Fingrid Oyj, 2018c)

Even if Datahub does not necessary show any significant changes in customer's daily life, it enables customers to have more active role as both electricity consumer and producer. This is especially due the improved data exchange to third parties. Datahub's new online service allow customers to have access and check their information stored in Datahub and manage the authorizations they have given to third party. Customers can check the information of them authorized parties have searched/retrieved from Datahub. (Fingrid Oyj, 2018c)

As mentioned above, third parties will have better access to customer data stored in Datahub. This allows their better participation and operation in Finnish electricity market. Third party need to make service contract with Datahub, which defines the access to customer data. To inform that customers have authorized the third party to have access to their data, Datahub offers a data transfer interface for third parties to submit information about authorization. Other option is that customer announce this authorization via online portal. (Fingrid Oyj, 2018c)

Datahub offer standardized interfaces for third parties. (Fingrid Oyj, 2018c) Standardized interfaces promote creating more ICT-solutions and new services, that require utilization of prosumer's or consumer's metering data. This way Datahub ease the entry of new players into the market. (Fortum Corporation, 2017)

3.4.2 Data security and privacy in Datahub

Datahub promise to guarantee full data security and data privacy for data storage and exchange processes. Datahub defines every information that can be attached to a customer as personal data. (Fingrid Oyj, 2019b) Datahub and market processes in it are designed in a way that only data that is necessary to market processes is stored in Datahub. Market parties can only search information of which they have been authorized in advance. These rights depend on the role of market party and the contracts made between electricity prosumers and consumers. (Fingrid Oyj, 2018c) Centralized data storage and standardized information exchange between market parties enable more efficient monitoring of incorrect practices as well. (Fingrid Oyj, 2019b)

4 CASE STUDIES

This chapter includes four case studies which illustrate information flows between households and other electricity market parties in Finnish electricity market now and in the future. Information flows are made mainly from the future household's point of view. The purpose of the case studies is to illustrate information flows that are related to data and information collected from households, and information flows about utilization purposes of this data and information (refers to business processes).

Case studies were provided for this research by the case company. The case company is one of the biggest city-owned Energy Companies in Finland. They produce and sell electricity and district heat and offer natural gas for industry. Case company also offers various smart energy solutions for electricity end-users. These solutions include solar panel systems with intelligent monitoring possibilities. Households can utilize these systems to produce and use their own electricity. This way company encourages Finnish consumers to deploy environmentally sustainable solution and became a prosumer of renewable energy.

The case company was selected by the recommendation of Partiture Oy. Case company was selected to this thesis because they have similar new energy solution which they offer for their customers as were discussed earlier in this thesis. Interviewees with the case company were chosen based on their responsibilities in case company. Interviewees' daily work is among new energy solution, which is why they were asked and selected for interviews.

Case studies were selected by evaluating which case studies are needed to examine in order to illustrate both the current information flows and the future information flows related to households. The first Case study was selected to be about a basic consumer living in Finland in order to illustrate household related information flows in the current Finnish electricity market. The second Case study, which present the future prosumer who utilize solar PV system, was selected in order to analyze information flows related to future prosumer. The third Case study was selected in order to visualize Datahub's effects to information flows. The fourth Case study was selected in order to illustrate information flows related to future household who utilize some other new energy solution than solar PV system. This way information flows and the changes in these flows in the future could be illustrated and analyzed more reliably.

Examined information flows were selected based on the interviews made with the case company. These information flows were selected as the most important information flows that transfer customer's data or information, and the most important utilization processes (business processes) of this data and information.

Research method was open ended unstructured interviews. There were three interview sessions held. One was kept as face-to-face meeting with product manager of solar PV systems of the case company. The other interview was also done by face-to-face meeting with two interviewees: product development specialist and sales and client relations manager of the case company. The third interview was done by phone with sales and client relations manager. This first Case study was made based on literature review in Chapters 2 and 3, and interviews made with case company. The second Case study was as well made based on literature review about the PV system components and interviews. Third case was made based on the literature available from Datahub and interviews. Information flows related to Case study 4 were discussed and illustrated briefly based on existing pilot project.

The structure of the case studies follows the repeated pattern. The first two case studies have own sections for discussing about metering data from smart meter, general customer information, business processes and overall information flows. In addition to this, Case study 2 discusses other necessary business processes and metering data from solar inverter in own sections. Case study 3 introduces only one information flow figure, and all the flows are discussed in the same section. Case study 4 differ from other case studies as it is made based on existing pilot project, and the evaluation of information flows are only made based on document published from the pilot project.

4.1 Case study 1: Information flows related to basic consumer

This first Case study observes current household who does not utilize solar PV systems, HEMS or other new energy solutions in their homes.

Metering data from smart meter

One of the main information flows in Case study 1 are flows that consists of metering data from smart meter (Figure 12). Smart meter, which is capable of measuring two-way electricity and information transfer, is placed between the grid and the household. The DSO is responsible for distributing electricity to household and metering the electricity flow between household and the power grid. DSO then provides household's metering data from smart meter to authorized market parties like ER. Information flows related to metering data from smart meter and its disclosure to other electricity market parties are shown in Figure 12.

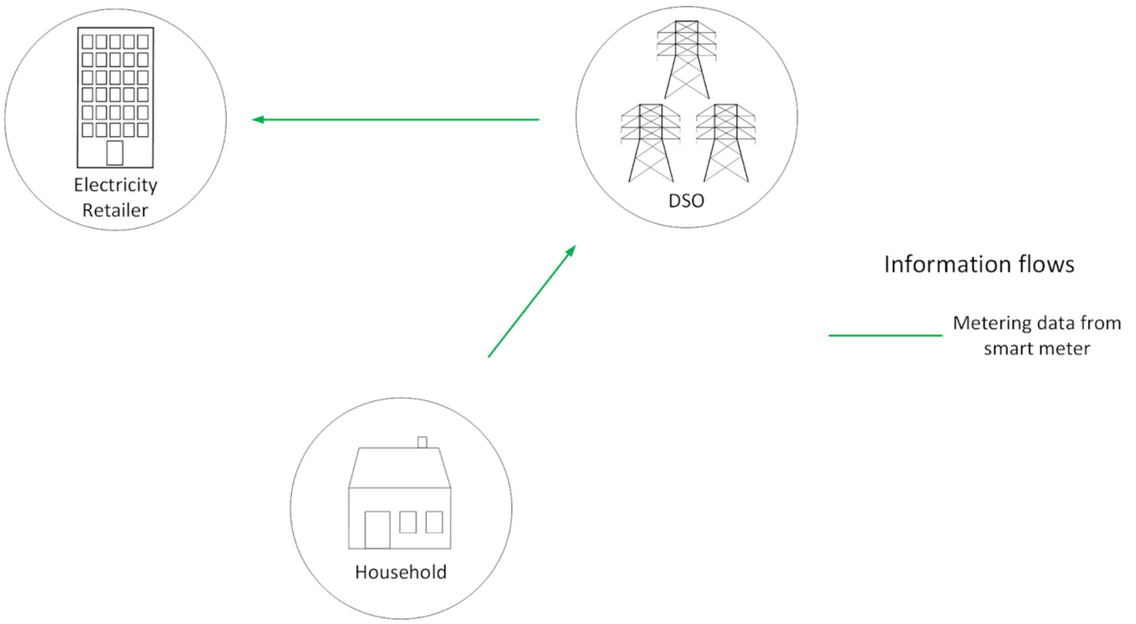

Figure 12. Information flows related to metering data from smart meter and its disclosure to other market parties in Case study 1.

General customer information

General customer information refers to customer information, address information and billing information collected from customer. Customer (household) needs to provide general customer information for both ER and DSO in order enable necessary business processes. Currently the most recommended practice is that customer makes an electricity selling contract with ER first, and then authorize ER to make electricity transfer contract with DSO for customer. In this Case study 1, customer provides general customer information for ER, which then provides it to DSO in the process of making electricity contracts for customer. Information flows related to disclosure of general customer information are shown in Figure 13.

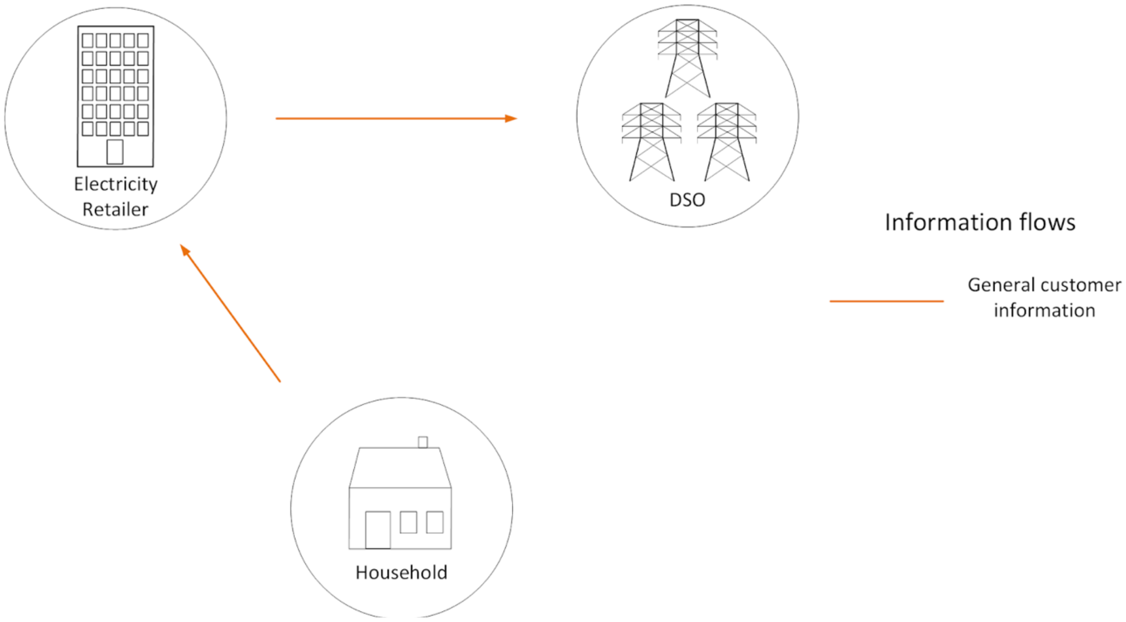

Figure 13. Information flows related to general customer information and its disclosure to other market parties in Case study 1.

Business processes

The most relevant business processes that DSO and ER practice related to the customer in Case study 1 includes contract processes, billing processes and offering customers access to their metering data from smart meter. Information flows that refer to these business processes are illustrated in Figure 14. These processes require utilization of general customer information and household's metering data from smart meter. DSO also informs their customers about possible disruptions in distribution caused by pre-planned grid improvement processes or due storm damage. Informing requires utilization of general customer information.

Customers (households) need to make a contract for electricity transfer and electricity selling. In electricity transfer contract, households agree with DSO about the electricity transfer, electricity data metering and utilization of this data. Customer gives agreement for metering data collection and utilization by signing this contract. Contract needs to be signed before electricity is transferred to household.

In addition to electricity transfer contract, customer need to make an electricity selling contract with ER of their choice. In electricity selling contract, household agrees about buying the electricity from a retailer. Household also gives agreement to ER in this contract to have access to its metering data from smart meter in order to enable necessary business processes. Customer can also authorize ER to provide necessary customer information related to necessary business processes to DSO. Also changes in household's contracts with ER and DSO are included to these business processes.

In addition to contract processes, ER and DSO need general customer information and metering data from smart meter for billing activities. Bills sent by DSO and ER to customer include information about customer's electricity usage as well, which is why bills acts as one channel for providing customer information about their electricity consumption. As discussed in Chapter 3, DSO is responsible for providing hour-based metering data from smart meter to customer (normally via online-service). ER is responsible for providing a consumption report and comparison information with other households for their customers once a year. In this Case study 1, prosumer has access to its hourly metering data measured from smart meter via online portal from ER instead of DSO. This practice is agreed with DSO and ER in the case company.

Figure 14 shows information flows related to business processes in Case study 1. In this case, information flows between ER and DSO refer to contract processes. Flows from ER to household include billing processes, contracts, providing metering data via online service and providing a yearly consumption report. Flows from DSO to household refer to billing and contract processes and information exchange related to disruption in distribution.

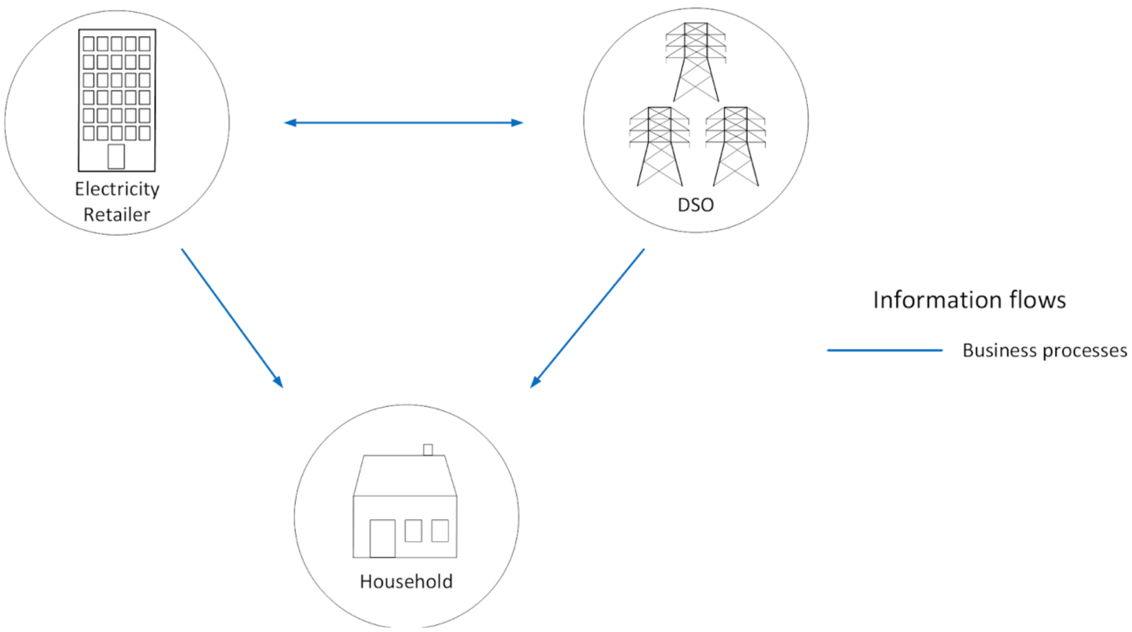

Figure 14. Information flows related to business processes among market parties in Case study 1.

Overall information flows

Currently ER and DSO both need at least general customer information and metering data from smart meter in order to practice their business with a basic consumer. Figure 15 shows overall information flows in Case study 1.

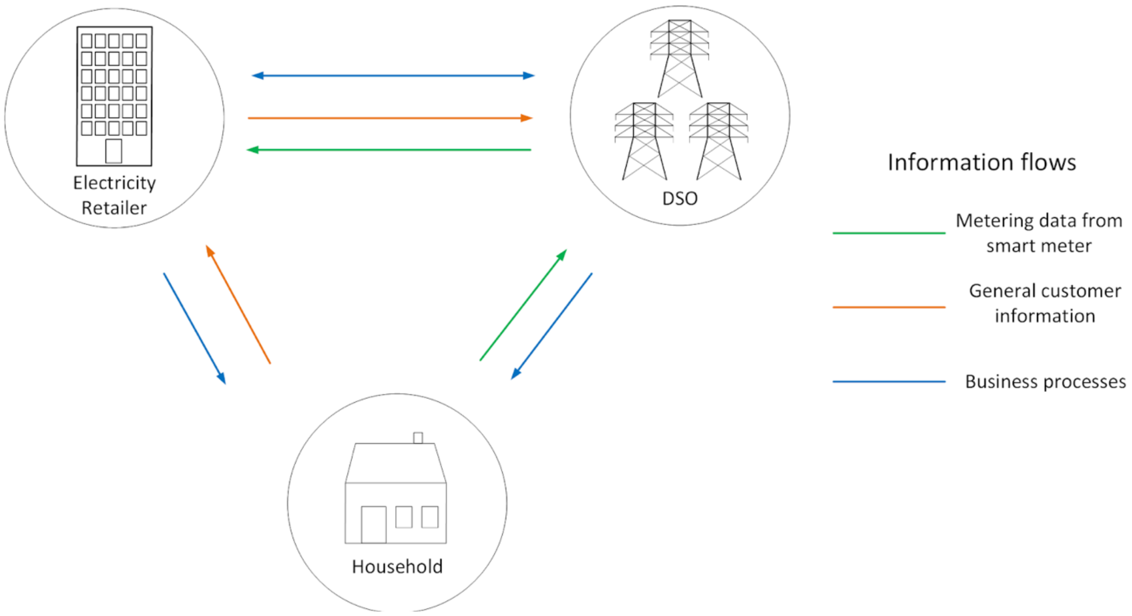

Figure 15. Overall information flows in Case study 1.

4.2 Case study 2: Information flows related to prosumer with solar PV system

The second Case study observes information flows related to prosumer who produces electricity with solar PV system.

4.2.1 Solar PV system solution in Case study 2

Solar PV systems that case company provides include variety number of panels depending on customer's needs, and an inverter. Case company provides solar PV systems with installation service, so customers purchase these PV systems as a turn-key package. There are two types of panels in case company's solar PV system solutions. One type is produced by Naps Solar System Oy in Estonia, and another type is imported from Asia. Naps Solar is an importer of these panels. Naps Solar is a solar electricity solution provider from Finland. (Naps Solar System Oy, 2019) Inverter that comes with case company's PV system solution is provided by Fronius International, an inverter provider from Germany. (Fronius International, 2019) Figure 16 shows the main components of the case company’s solar PV system solution.

Figure 16. The main components of the case company’s solar PV system solution: NAPS solar panel and Fronius inverter.

4.2.2 Information flows

In this Case study, there are two devices that collect electricity data from prosumer: solar inverter and smart meter. Other information collected from prosumer by DSO, ER and other market parties include general customer information and some detailed information.

Metering data from solar inverter and related business processes

Solar inverter used in this Case study 2 measures electricity generation data from prosumer’s solar PV system (Figure 17). In addition to electricity generation, inverter is capable of measuring for example output, yields and consumption. If prosumer would have integrated energy storage, this inverter is also capable for measuring energy balance or the state of charge of this energy storage. (Fronius International, 2019) In this Case study prosumer does not utilize energy storage.

Market party who measures this metering data from solar inverter is the inverter provider. Measured data goes to inverter provider’s systems. Case company does not have access to case prosumers metering data from solar inverter. In this Case study, inverter provider offers their customers access to metering data from inverter by web-based online portal. Registration to this online portal is free for customers who utilize provider’s inverters. Online portal allows prosumers to monitor and analyze their electricity production with solar PV system, as it shows metering data collected from solar inverter. Prosumer has access to all its up-to-date metering data from solar inverter anytime, and it can be viewed using home computer, tablet or smartphone. All the collected data from inverter is transferred to online system by using a Datamanager that is integrated to the inverter. With online portal prosumers can observe this data and for example optimize their self-consumption. (Fronius International, 2019)

Information flows related to metering data from solar inverter and its disclosure to prosumer (business process of inverter provider) are illustrated in Figure 17.

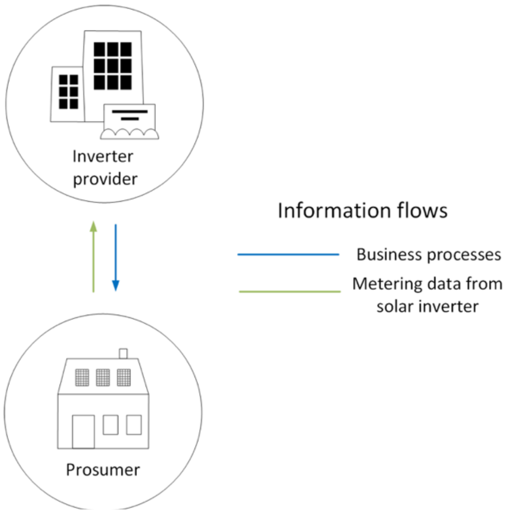

Figure 17. Information flows related to metering data from solar inverter and related business processes.

To have access to their metering data, prosumers need to register to inverter provider's online system. Registration to this system may require prosumer to provide serial number of the inverter, prosumer's email and some other information to inverter provider. Usage of online system may also require signing some privacy policy related to prosumer data utilization. This thesis excludes observation of these information exchange and business processes. Consideration of other utilization processes of prosumer's metering data from solar inverter is also excluded.

Metering data from smart meter

Just like in Case study 1, electricity metering data of prosumer is collected with smart meters. Finnish regulation requires that electricity transferred to the grid needs to be measured separately from the electricity taken from the grid. This is why prosumer's smart meter collects more data compared to household in Case study 1. Information flows related to metering data from smart meter in Case study 2 looks the same as in Case study 1, as the disclosure of this data is similar than in Case study 1. These flows are illustrated in Figure 18.

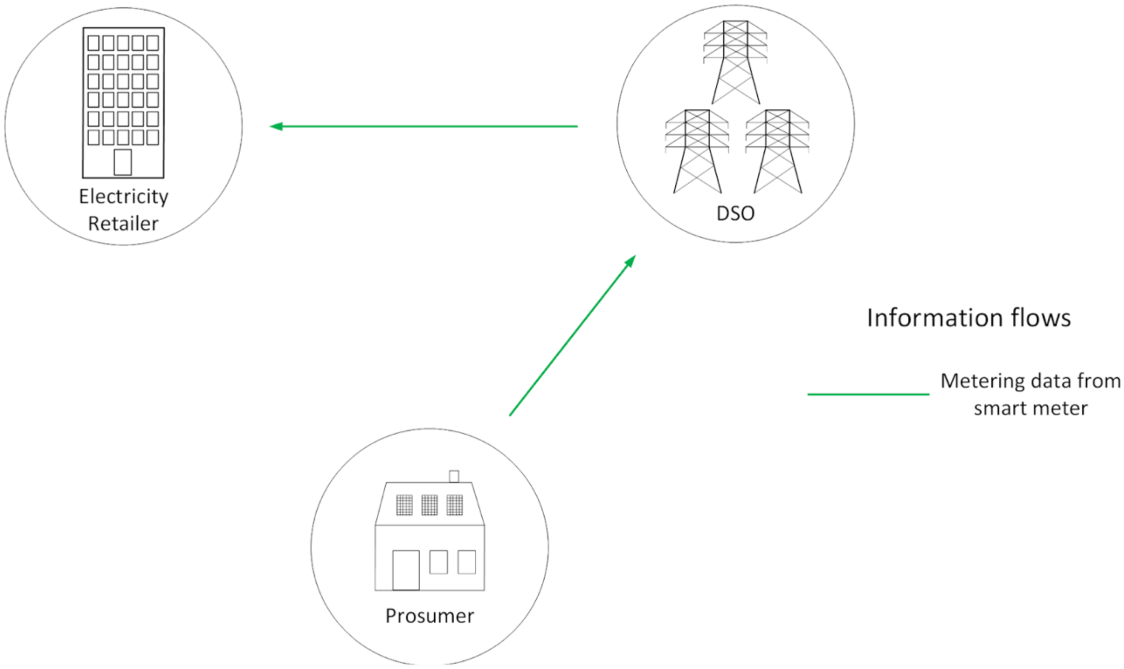

Figure 18. Information flows related to metering data from smart meter and its disclosure to other electricity market parties in Case study 2.

General customer information

Information flows related to general customer information and its disclosure to other market parties in Case study 2 are illustrated in Figure 19. Just like in Case study 1, ER and DSO need to collect general customer information from prosumer in order to provide their services and products to prosumer. Information flows related to collecting and disclosure of general customer information between prosumer, ER and DSO then looks similar than in Case study 1.

Other market parties in this Case study 2 utilize general customer information as well. Solar panel provider and installation service provider need to use general customer information in order to practice their businesses. Installation service provider needs customer's name and address (these are included in general customer information) in order to install PV system to customer's home. After installation, installation service provider delivers the installation minutes with customer's signature to ER. Solar panel provider needs general customer information for delivering of panels and for billing services. This customer information is provided for these market parties by prosumer's ER, as prosumer in this Case study 2 does not offer this information for solar panel provider or installation service provider.

As discussed earlier, utilization of online service of inverter provider may require utilization of general customer information. If so, this data is collected straight from prosumer by inverter provider. Prosumer's DSO or ER do not transfer any information about the customer to inverter provider.

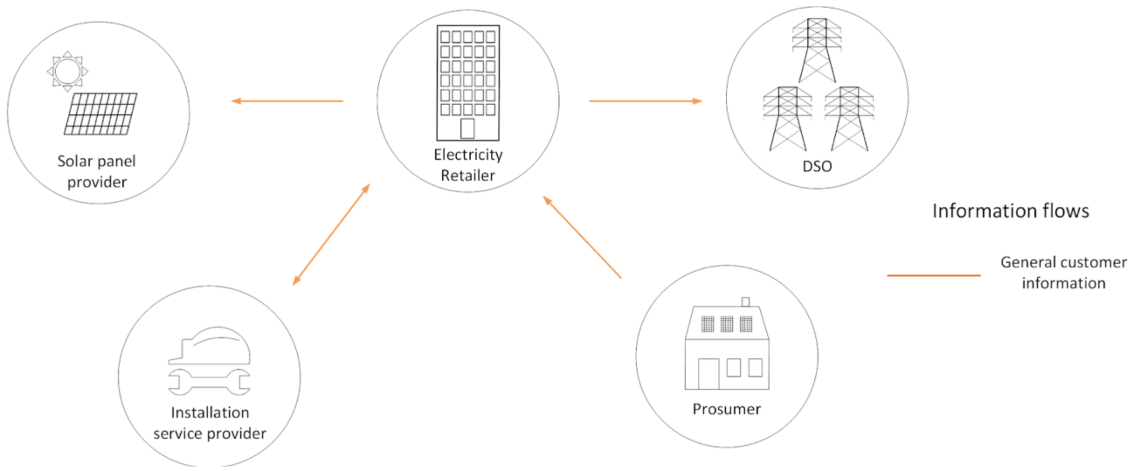

Figure 19. Information flows related to prosumer's general customer information and its disclosure to other market parties in Case study 2.

Business processes

Figure 20 shows information flows related to business processes in Case study 2. ER and DSO utilize metering data from smart meter and general customer information for the same business processes than in Case study 1, though there are some new contracts included in contract processes. Prosumer needs to make two contracts with its ER: energy selling contract and buying contract of small-scale electricity production. On this buying contract prosumer's ER agrees to buy the excess electricity produced by prosumer's solar PV system that is not used by prosumer. Prosumer also needs to make two contracts with its local DSO: electricity transfer contract and contracts for transferring prosumer's excess electricity to the grid.

Like mentioned in general customer information part, installation service provider utilizes customer information for solar PV system installation process. Solar panel provider utilizes customer information for its panel delivering and billing processes, so there will be information flows between solar panel provider, installation service provider and prosumer.

In Case study 2, information flows between ER and DSO refers to contract processes. Flows from ER to household include the same processes as in Case study 1, which are billing processes, contracts, providing metering data via online service and providing a yearly consumption report. Flows from DSO to household also refer to billing, contract processes and information exchange related to disruption in distribution. Flow from installation service provider refers to solar PV system installation process, and flow from solar panel provider to prosumer refers to delivering process of solar panels and billing processes. Business processes between inverter provider and prosumer were discussed in separate section earlier, which is why this flow is not illustrated in Figure 20.

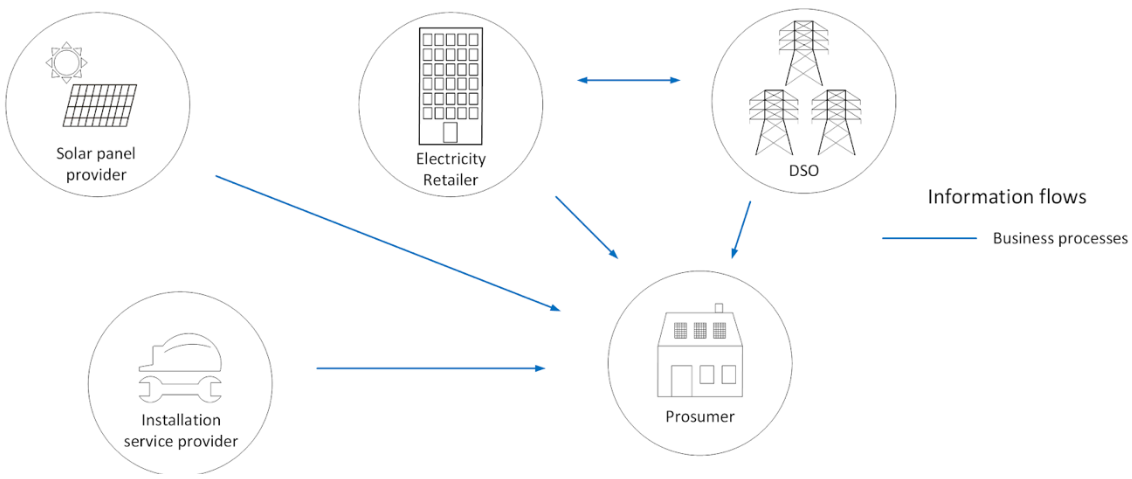

Figure 20. Information flows related to business processes among market parties in Case study 2.

Other necessary business processes

In this Case study 2, it is necessary to notice that there are business processes that need to happen in order to offer households solar PV systems. These processes take place between ER, solar panel provider and installation service provider and are illustrated in Figure 21. In order to offer households solar PV systems, ER needs to agree about pricing and the processes and the terms of cooperation with both solar panel provider and installation service provider. These business processes do not require utilization of general customer information or any kind of metering data from household, but in order to offer households solar PV systems, ER need to agree with these issues in contracts between solar panel provider and installation service provider.

Information flows related to these business processes which do not utilize household data or information but are necessary to happen in Case study 2 are illustrated in Figure 21.

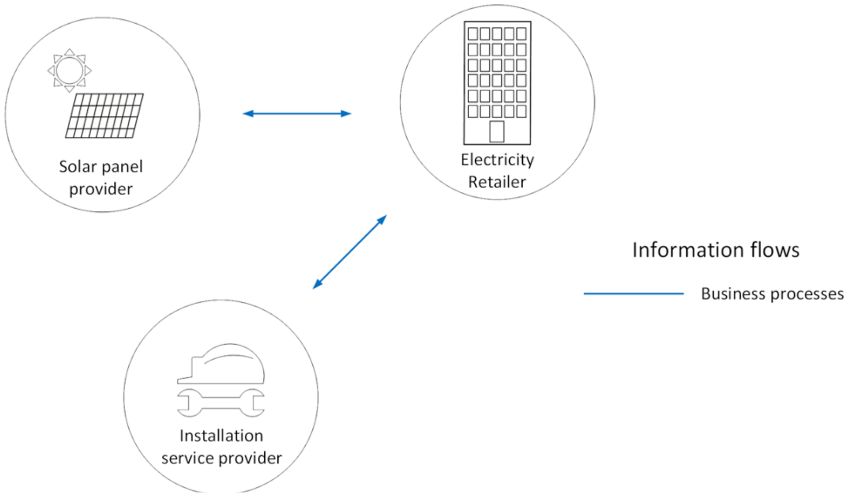

Figure 21. Information flows related to other necessary business processes among market parties in Case study 2.

Overall information flows

Figure 22 illustrates the overall information flows of Case study 2. Information flows from Figure 21 are not included in overall information flow figure ad those do not utilize household data of information or utilization of this data.

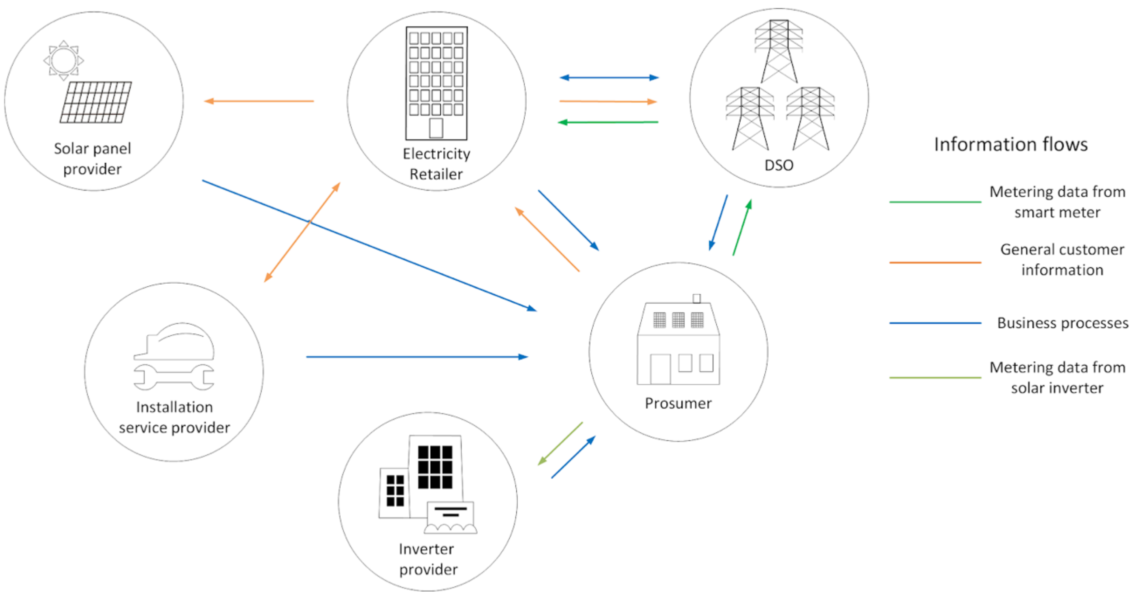

Figure 22. Overall information flows in Case study 2.

4.3 Case study 3: Information flows after Datahub implementation

Case study 3 observes information flows related to prosumer from in Case study 2 after Datahub implementation. This chapter is made based on Section 3.4 and the interviews.

Datahub will change the current information flows in electricity sector. Bilateral information exchange between market parties will be replaced with centralized information exchange system, of which every market party discusses only with Datahub. Only in rare cases will ER and DSO have to discuss directly with each other after implementation of Datahub. Datahub changes information flows between both existing and future market parties who utilize prosumer or consumer data in their business processes. These new information flows are illustrated in Figure 23.

In this Case study 3, information flows between Datahub and DSO&ER are illustrated based on who has the responsibility for accuracy and updating of certain customer data. When Datahub is in use, the direction of information flows is not so definite, as for example DSO can also send an update request for general customer information to Datahub. (Fingrid Oyj, 2018c)

Illustration of information flows after Datahub implementation

<u>Datahub and DSO & ER</u>: Business processes of DSO and ER in Datahub environment were discussed more closely in Chapter 3. Basically, the biggest difference from the current processes is that DSO is responsible for delivering metering data from smart meter to Datahub, and ER have access to this data from there. Another change is that ER provide general customer information to Datahub, and DSO have access to this data straight from Datahub. This way bilateral information exchange among DSOs and ERs will change to go through Datahub, and information flows between ERs and DSO disappear in most of the cases.

<u>Prosumer and DSO & ER</u>: From a perspective of prosumers (and electricity consumers as well), Datahub does not bring any direct significant change in information flows. When Datahub is in use, prosumers still offer general customer information to ER as they currently do, and metering data from smart meter is collected by DSO. The only difference is that information flows related to prosumer's access to its metering data may change. Datahub will provide customer access to its metering data from smart meter via online service in the future, but existing services of ER and DSO may be available also

in the future. Data gathered from smart meters and general customer information will be used for the same business processes that DSO and ER currently utilize it. In conclusion, information flows between prosumer and DSO & ER will not change after Datahub implementation. Nevertheless, Datahub will have indirect impact also on consumer, as it provides equal and simultaneous access to information for all energy market parties, which will benefit the consumer as well.

Datahub and prosumer: Datahub is responsible for providing customer's access to its metering data from smart meter. Prosumer's (and consumer's) access to their metering data will be provided by Datahub. New service portal, Suomi.fi, enables prosumers and consumers to have access to their centralized metering data and also manage their authorization information. DSO and ER can still continue providing their customers access to their metering data via online service after Datahub as well, but they do now have responsibility to do so. Prosumers can observe and manage authorization information via online service as well. Due these changes new information flows between Datahub and prosumer are created.

Datahub and new service/product providers: There might be new information flows between Datahub and solar inverter provider in the future. Datahub offers standardized interfaces for third parties, who can utilize those for creating and offering new solutions for electricity end-users. An example of this kind of situation may occur if solar inverter provider creates an online service which provides prosumer's access to its both the metering data from smart meters and metering data from solar inverter via same online service. In this Case study 3, service provider would have access to prosumer's metering data from smart meter from Datahub. Datahub's interfaces then enable creation of new information flows between Datahub and new service providers. It is not certain that inverter provider in Case study 2 would offer such solution. It is also unlikely that solar panel provider or installation service provider in this Case study 3 would make a service contract with Datahub just to have access to general customer information of prosumer. This is why information flows between Datahub, and new service/product providers are not illustrated in overall Figure 23. It is still relevant to notice that Datahub offers possibilities for these information flows to take place.

Prosumer and new service/product providers: Information flows between prosumer and service/product providers will not necessarily change after Datahub is implemented in Finland. The contracts made between new service/product providers and prosumers may utilize customer information which is also stored in Datahub, but the access to this information will most likely be provided by prosumer's ER also in the future. Information flows related to possible contract processes and metering data from solar inverter will most likely stay between prosumer and service provider in the future.

Illustration of overall information flows after implementation of Datahub is shown in Figure 23.

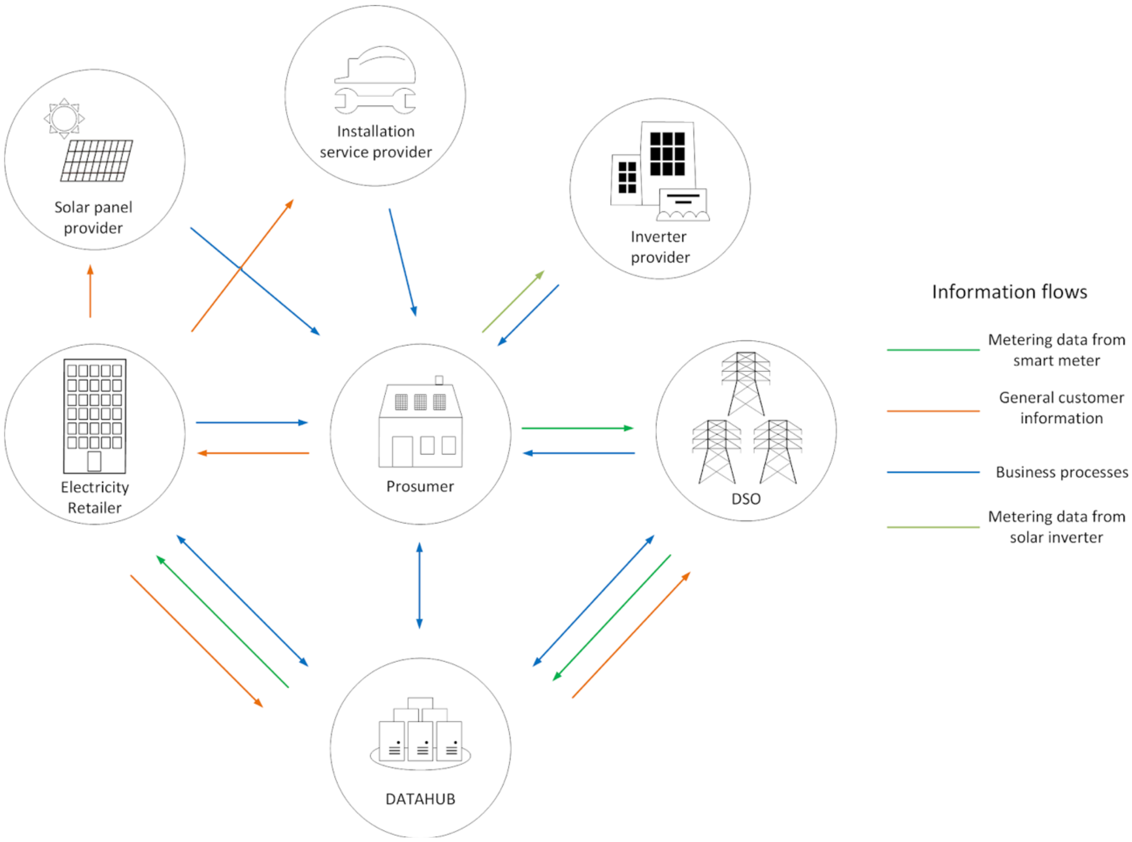

Figure 23. Illustration of the possible overall information flows in Case study 3.

4.4 Case study 4: Information flows related to household with HEMS

This Case study 4 observes household who utilize HEMS in participating on demand response activities.

4.4.1 Information flows related to households with HEMS

One pilot project examined how home energy management system could be used in aggregating loads in demand response market. The pilot project was made by There Corporation Oy and Fingrid Oyj in year 2016. (There Corporation Oy, 2016) This pilot project is used as an example in illustrating information flows related to HEMS and demand response activities.

The examined solution included case in which loads from households who utilize direct electric heating were controlled by HEMS and utilized to demand response activities. There's cloud service is a database-controlled application which collected the information of the electricity loads and electricity consumption of households and used it for controlling the heating. ThereGate was a control unit that was used in pilot project. It was located in households to convey the control information and communicate the metering data from household to cloud service. In addition to these, the examined solution included separate user interfaces for electricity user and operator. User interface for operator was used in load control activities, and user interface for electricity user enabled consumer to monitor and control the heating of household. The actual controlling of home heating system happened automatically in accordance with the settings that customer had set in advance. (There Corporation Oy, 2016) Pilot project's upper level illustration in Figure 24 shows the simplified solution used in pilot projects.

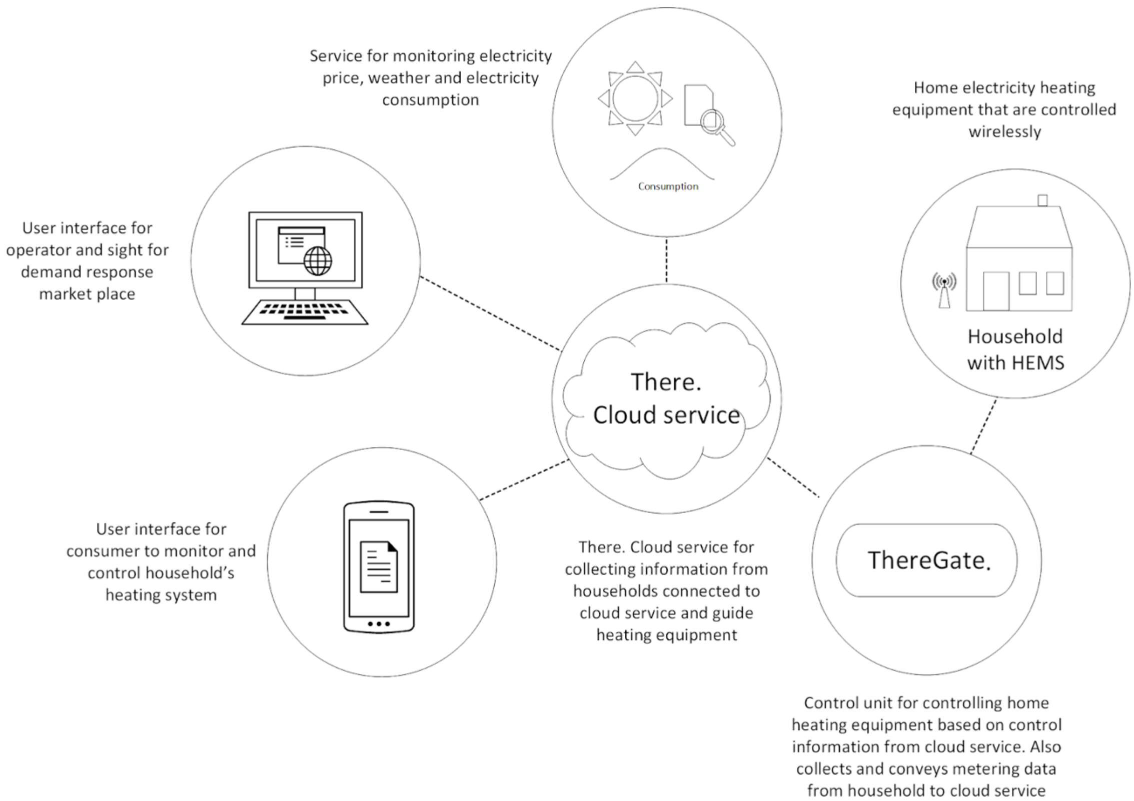

Figure 24. Simplified solution used in demand response pilot project. (Based on There Corporation Oy, 2016)

There Corporation offers ThereGate device to energy companies and other retailers, who resell it to household customers. There Corporation also provide solution that is possible to connect with solar PV system. (There Corporation, 2018) In the pilot project solar PV system was not included to the case.

Information flows between household and aggregator depend on the automation architecture and communication solution applied. (Ikäheimo et al., 2010) Household's electricity loads can be controlled and communication managed at least in three ways. The first way is to control the loads by using the relay in automatic meter reading device. The second is to control commands transferred from the power grid or other system to building automation system. The third method is to use separately implemented home energy management system or building management system for controlling loads. (Järventausta et al., 2014) In observed pilot project, communication was managed through aggregator's own control unit, which sent control commands to home's electricity heating equipment. (There Corporation Oy, 2016)

Aggregator utilized household's metering data from smart meter among other data collected with home energy automation system. Real-time consumption data was gathered from households and sent to HEMS by using control device, ThereGate. (There Corporation Oy, 2016) In ThereGate solution, data is read from smart meter by using optical meter reader and send to control unit in every 5 minutes. (Fortum Markets Oy, 2014) Other data that HEMS collected from household in pilot project included room temperature, household's electricity loads and parameters about acceptable temperature limits. (There Corporation Oy, 2016) Figure 25 illustrates the possible information flows in Case study 4.

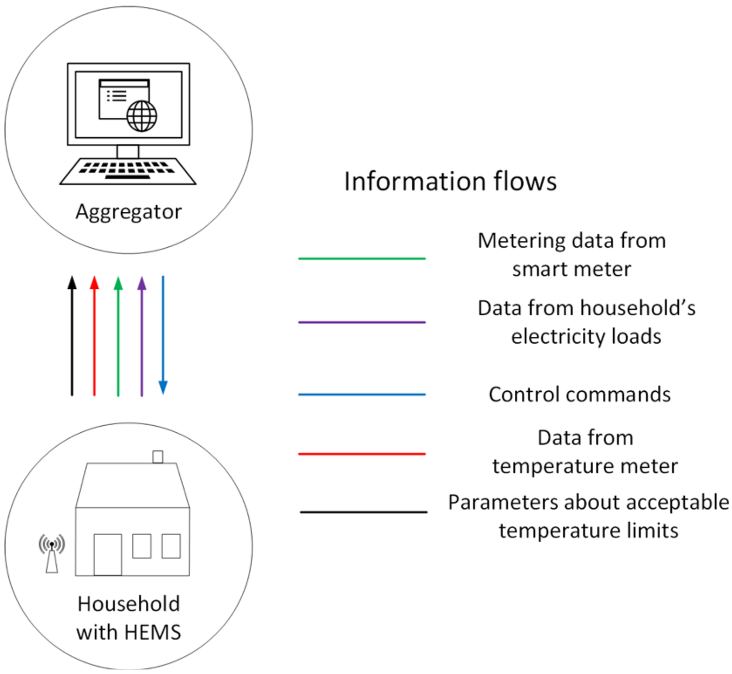

Figure 25. Illustration of the possible information flows in Case study 4. (Based on There Corporation Oy, 2016)

4.4.2 Limitations for Case study 4

In this Case study 4, information flows between household with HEMS and DSO, ER and Datahub were not illustrated. This is because the data collection, transfer and utilization processes of this data was not examined in the pilot project which formed the basis of this Case study 4. Information flows that are related to for example data utilization in contract and billing processes between household and aggregator, ER and DSO will most likely exist, but because of these business processes were not discussed in the pilot project, related information flows were not illustrated. This decision was made in order to avoid assumptions in information flow figures. Only information exchanges that were mentioned in pilot project's material were illustrated as information flows in Figure 25. Based on the existing research there will probably be new information flows also between aggregator and ER or DSO. (Ikäheimo et al., 2010) Pilot project indicated that information flows between aggregator and other market parties than ER or DSO will take place in the future as well, as there will be data transfer between aggregator and other market parties. (There Corporation, 2016) These information flows were not examined more closely in the pilot project and therefore those were excluded from this Case study 4.

Information flows in Case study 4 does not consider information flows between other market parties than HEMS provider and aggregator in the future. Some of these market parties (ER, DSO and Datahub) and their information flows between households were discussed in previous case studies in this thesis. ER, DSO and Datahub will also make information exchange with households who utilize HEMS in demand response activities, but these flows were not discussed in the pilot project. For that reason, Case study 4 did not illustrate flows between these market parties and household with HEMS either. Nevertheless, it is important to notice that in the future, there will probably be similar information flows among households and other market parties that were illustrated in Case study 3.

4.5 Analysis about information flow changes due to the utilization of new energy solutions

This section provides an analysis of changes the information flows that happen due to the utilization of new energy solutions is provided in this section. The analysis was made by comparing the information flow illustration of the basic consumer to information flow illustrations of the future households with new energy solutions. The analysis reveals the followings:

1. The amount and content of data and information produced by households will increase and become more diverse in the future

Households with new energy solutions will produce more data and information compared to the basic consumer. This can be noticed when analyzing information flows in different case studies made in this chapter. In Case study 1, data and information that current household produced included metering data from smart meter and general customer information. Future prosumer in Case study 2 produced also metering data from solar inverter in addition to data and information produced by current household. In Case study 3, the amount of data and information did not increase because of Datahub, so data produced by household was similar than in Case study 2. Case study 4 revealed that households who utilize HEMS in participating on demand response activities produced even more data and information than future prosumer in Case study 2. Produced information and data in Case study 4 included household's electricity loads, room temperature and parameters that set acceptable temperature limits. Comparison about the amount of data and information produced by households now and in the future reveals that the amount of data and information produced by households will increase in the future when household utilize new energy solutions. Comparison of case studies 2 and 4 reveal that the content of data and information produced will also become more diverse. Instead of producing only metering data from smart meter and general customer information, future households will produce data and information about their electricity generation, electricity loads of smart home appliances and some new data like room temperature and parameters for acceptable limits for controlling home's room temperature.

2. The number of information flows between households and other market parties will increase in the future, and the content of these flows become more diverse

Previous finding about increased amount of data and information production will cause changes in information flows between households and other market parties. This can be noticed when comparing information flows illustrated in case studies. Increase in information flows can be noticed in Case study 2, in which new information flow including general customer information is formed between ER and installation service provider. New information flows are also formed between ER and solar panel provider and installation service provider. Case study 2 also reveals that new information flows between prosumer and inverter provider are formed. The content of these flows between prosumer and inverter provider is also different type compared to information flows related to the basic consumer in Case study 1.

Another example of increased number of information flows and the change in the content of these flows was provided in Case study 4. Case study 4 revealed that various kinds of information flows between household and aggregator are formed. Information flows that included other data than metering data from smart meter were new information flows created by the utilization of HEMS.

Utilization of Datahub will also increase the number of information flows, which can be noticed in Case study 3. New information flows are formed between Datahub and ER&DSO, but the content of these flows does not remarkably change. New information flow between Datahub and prosumer is formed as well. Even though this thesis outlined the information flows between new electricity market parties and Datahub, there are possibilities for these flows to exist in the future. In this case, there Datahub would create even more new information flows in the future Finnish electricity market.

Analyzation of case studies reveal that information flows will change due utilization of new energy solutions in households. When the amount of data and information produced by households increases, the number of information flows increases as well. Information exchange among market parties will increase due to new data and information production and utilization, which will result creation of new information flows. Diversity of data and information produced increase also the diversity of information flows in the future. Case studies in Chapter 4 clearly show the increase in the number of information flows and the diversity in the content of these flows among electricity market parties in the future.

3. Data and information produced by households will be utilized more broadly to new purposes in the future

The utilization purposes of household data include necessary business processes that ERs and DSOs currently practice. These processes were discussed more closely in literature review in Chapter 3 and in Case study 1. Interviews with the case company and literature review revealed that these current business processes of ERs and DSOs that utilize data produced by households will continue existing in the future. Some of the business processes might change a little through new solutions, as was noticed in examination of contract processes in Case study 2. Case study 3 also showed that the utilization of future household data will stay mainly the same after Datahub implementation, only the access of customer’s data will change.

In addition to existing business processes, there will be new ways to utilize data and information produced by households. Examples of new utilization purposes of customer data and information were shown in case studies 2 and 4. Case study 2 revealed that utilization purposes of general customer information will become more wider compared to current state. New market parties in Case study 2 included installation service provider and solar panel provider. These market parties utilize some part of the general customer information in their business processes, which does not currently exist. Installation of solar PV system is new business process that require utilization general customer information, and solar panel provider’s billing and solar PV system delivering processes are new utilization purposes of general customer information as well. In Case study 2, metering data from solar inverter was new data produced compared to household in Case study 1. Collecting this new data made it possible for inverter provider to have new business process, which was providing their customer’s access to their metering data from solar inverter. This business process is not the same that providing customer’s access to their metering data form smart meter. By utilizing data from solar inverter, household could monitor their own electricity production.

Case study 4 showed new utilization purposes of data and information produced by households. New utilization purposes, like monitoring and controlling household’s smart electric appliances with HEMS, utilize both the existing and new data and information produced by household with HEMS. Data that is already produced in households (metering data from smart meter) and new data produced in the future (room temperature, household’s electricity loads) are used also by new market party (aggregator) in controlling household electric appliances and practicing demand response activities. Case study 4 then indicated that new kind of household data and information can be use in various purposes, for example managing and controlling home energy appliances by households or, from the aggregator’s point of view, managing the demand response in power grid.

5 RESULTS

This chapter presents the results of this research. The results are provided for each research questions separately.

What are the most important information flows related to basic consumers?

The most important information flows related to basic consumers are flows that consist of metering data from smart meter, general customer information and business processes that utilize the content of these flows. These information flows are necessary for basic consumers in Finland who use electricity from the power grid in their homes.

Metering data from smart meter is necessary for basic consumers as it informs the DSO and ER how much electricity consumers have consumed. These market parties utilize this information for the necessary business processes, for example billing, with consumer.

General customer information is one of the most important information flows related to basic consumer because market parties need this information in order to practice their business with consumer. Both ER and DSO of consumer utilize general customer information for necessary business processes, including contract processes, billing processes and providing customer’s access to their metering data.

Information flows that illustrate these necessary business processes that ER and DSO practice are also important flows related to basic consumer. Without these business processes which utilize customer data and information, customers could not utilize electricity from the power grid.

What new information flows are created by the utilization of new energy solutions in households?

Various new information flows are created by utilization of new energy solutions in households. A new information flow that consists of metering data from solar inverter is created when the prosumer utilizes a solar PV system. This new data flow will also create a new information flow that refers to business processes of the solar inverter provider. Utilizing a solar PV system also will also create new information flows between ER, solar panel provider and the installation service provider. The new information flows between the ER and the solar panel provider consist of general customer information and necessary business processes related to billing and delivering of solar PV systems. The information flows between the ER and the installation service provider consisted of general customer information and business processes related to installing solar PV systems to customer's home. The installation process of solar PV system creates a new business process information flow between the installation service provider and prosumer.

There are also other necessary business processes among ER, solar panel provider and installation service providers which are necessary but do not transfer any prosumer data or information, neither refer to utilization processes of prosumer data and information. These new information flows are created by utilizing solar PV systems in households. In addition to these new information flows, utilization of solar PV systems in households cause changes in the content of existing information flows between the prosumer, the ER and the DSO. These changes are related to new contract processes and, therefore change the content of business process information flows.

How will the information flows change between households and other electricity market parties due to the utilization of new energy solutions?

The amount and content of data and information produced by households will increase and become more diverse in the future. The increased amount of data produced and collected, and the diversity of this data will affect the information flows between the households and other electricity market parties. The number of information flows between households and other electricity market parties will increase in the future, and the content of these flows will become more diverse due to the utilization of new energy solutions in the households. Data and information produced by the households will be used more broadly for new purposes in the future.

6 DISCUSSION

This research examined the changes in the evolving Finnish energy systems from a very specific point of view. The aim of this research was to investigate information flows in the future Finnish electricity market from the households' point of view. Even though this thesis shows similar results than can be found in the literature, there were no similar visualization models or illustrations found about information flows. Neither is there earlier research about the most important information flows related to basic consumers, nor about the new information flows to be created by the future households who utilize new energy solutions. For these reasons, relevant information flows were chosen to be considered in the case studies. The illustrations of the current and new information flows in the Finnish electricity market, and the analysis about the changes in these information flows in the future presented in this thesis cannot be compared with existing studies in a very comprehensive and detailed level. Notwithstanding, the findings made when evaluating information flow changes can be compared with some of the existing researches. (Hertrampf et al., 2018)

This research revealed that the amount of data and information collected from households with new energy solutions will increase and the content of collected data will become more diverse. This result is also supported by other researches. (Hertrampf et al., 2018) As discussed in Section 2.3, utilization of new energy solutions, such as solar PV systems and HEMS, will produce new types of data and information sources from households. Examples of these are; information and data about electricity loads of smart home appliances, generation data from solar PV system and room temperature information (Hertrampf et al., 2018 & Matallanas et al., 2012). The results of Chapter 4 are also in line with these researches.

The number of new energy solutions utilized may also affect the amount of data produced. The literature review in Section 2.3 revealed that a prosumer who utilizes PV system with integrated energy storage produce more data compared to a prosumer without energy storage (Fronius International, 2019). The Case studies in Chapter 4 discussed future prosumer (Case study 2), and households with HEMS (Case study 4). It can be assumed that, if households in the future utilize both of these new energy solutions simultaneously, the amount of data and information produced would include data from both of the examined Case studies. This would result in a greater amount of data and information generated by the households compared to the situation when the household utilizes only one of these two new energy solutions. Existing research (Matallanas et al., 2012) about household that utilize both solar PV system and home automation system simultaneously indicate the same result.

This research showed that changes in data and information collection and utilization increase the number of information flows among electricity market parties. Literature review from Chapter 2 support this finding. In Section 2.3 it was mentioned that utilizing new ICT-based services and products creates new information flows between households and energy service providers in the future. (Naus et al., 2014) Case studies clearly indicated the same result, which was increase in the number of information flows.

Broadening the utilization purposes of new data and information was also noticed in this thesis. As mentioned in Section 2.3, the future service providers will need to utilize large amount of customer data and information. This data and information will then be used to customize new energy solutions for the households' needs. (Fortum Corporation, 2017) HEMS is a good example about a new energy solution that produces and utilizes new kinds of household data and information in various new functions, such as demand response activities. (There Corporation, 2016) This broadening of data utilization purposes was also noticed in Case study 4.

Transparency, data security and privacy issues

This analysis about the information flow changes in the future clearly indicated an increased level of complexity related to information flows from households who will utilize new energy solutions in the future. The results indicate that complexity in data and information exchange between households and other electricity market parties will increase in the future due to the utilizing new energy solutions. Changes in information flows reveal that household data will be divided and utilized by various market parties. Both existing and new market parties will need access to household data in order to allow household to utilize new energy solutions. This requires that household with new energy solutions open their data to various market parties.

The role of information flows in adapting new energy solutions in households was discussed in Section 2.4 of this thesis. Information have been said to have an important role in redefining the relationships between households and energy providers. (Naus et al., 2014) It is possible that changes in information flows will affect the households' willingness to utilize new energy solutions. As discussed in Section 2.4, transparency in household data collection and utilization is one of the aspects that will affect the willingness to utilize new energy solutions. (Naus et al., 2014) Transparency in household data collection and utilization might even become even more relevant in the future, when the level of complexity increases.

Freedom of choice of households for their own smart appliance was also considered as a challenge related to the use of new energy solutions in households. (Naus et al., 2014) Case study 4 shows that this challenge is related to participating in demand response. In order to utilize HEMS in demand response actions, households need to open their data and hand it over part of the decision-making power for aggregator. An external control and utilization of households' smart appliances can raise concerns related to the power of control of homes (Darby, 2018). One way of creating positive attitude toward new energy solutions mentioned was to allow the customers having the final word in power of control of their homes and smart appliances (Ikäheimo et al., 2010). For example, in Case study 4, households would have the possibility of not responding to the aggregator's commands, and, therefore, hold the greatest power for controlling their home appliances. This power of control discussion will probably become relevant when households utilize HEMS for participating in demand response.

Data security and privacy were also discussed as an issue to consider when adopting new energy solutions. Privacy concerns have been noticed to limit the interest in adopting these new solutions in households (Gram-Hanssen and Darby, 2018). It is also claimed that the potential loss of privacy is a challenge that the adoption of new energy solutions will have to solve (Parag and Butbul, 2018). It was noticed that the digitalization of the energy system will require the development of even stronger data security (Energiateollisuus, 2018a). The digitalization of power grids and the increased amount of ICT-based services and products will require a simultaneous development of consumer privacy and data security, in order to tackle the challenges related to utilizing new energy solutions in households.

7 CONCLUSIONS

The Finnish electricity system is going through a major energy transition. This transition will cause various changes to our electricity network, the energy market and market parties. One of the main changes is the increased number of new energy solutions available for the households. In the future, households in Finland will have a more active role in the power grid via the utilization of new ICT-based energy solutions. If and when the households will utilize new energy solutions, such as solar PV systems and HEMS, they should also have possibilities to monitor their electricity usage and manage electrical devices at their home. Households will also have more possibilities to participate in demand response. In order to utilize these new energy solutions, households will need to allow increased amount of data collection and information exchange between their homes and other electricity market parties. This will change the information flows among electricity market parties in the future.

This research illustrated information flows in the future Finnish electricity market from the households' point of view. The thesis also evaluated how utilization of new energy solutions in households will change the information flows between households and other electricity market parties. In this research, new types of illustration methods for visualizing information flows among electricity market parties was provided. The information flow visualization figures provided an overview about the information flows related to both basic consumers and future households with new energy solutions. The information flow figures also illustrated the changes which will happen in information flows due to the utilization of new energy solutions in households.

The amount of data collected from households and the content of data and information will increase in the future. These changes will cause changes in the number and in the content of information flows among electricity market parties. The number of information flows in the future Finnish electricity market will increase due to the utilization of new energy solutions in households. The content of these information flows will also become more diverse. The households' data and information will also be utilized for new purposes in the future, which will also be seen as changes in information flows.

The results of this thesis can be used to improve the understanding of information flows in the future Finnish electricity market. The results can be utilized when considering ways to tackle the challenges related to utilizing new energy solutions in households. From a business perspective, the results of this thesis can be used in creating more transparent services in the Finnish electricity market.

Suggestions related to transparency, data security and privacy based on the research

New regulations will need to be set and further developed in order to ensure proper data security and privacy management related to Smart Grids. By preparing Smart Grid standards that set the general guidelines for electricity and other data management, organizations such as the European Standardization Organizations can promote proper data security management in the energy sector. The Finnish regulative authorities could make even stricter data security and privacy regulations if needed, when introducing new laws and standards in regulating The Finnish electricity market.

All market parties that measure or utilize customer data for any purpose should follow data standards and regulations related to household data management. Grid operators, such as DSO, ER, TSO, aggregators and other market parties should practice in transparent information exchange methods. The Datahub is a good step toward a transparent data exchange in the Finnish electricity market. Grid operators should engage in securing and protecting customers' data. Also the providers of new energy solutions need to develop their services and products for customers according to data standards and other related regulations. This will ensure that the solutions to be used by households will include proper security and management of data. For example, telecommunication providers, data processing service providers, and ICT equipment and system providers will have to ensure that their solutions ensure privacy and data security for their customers. As the market for new energy services (and especially solar PV systems) are global, the service provider or product providers might come from abroad. This might require some adjustments for service providers, as other countries might have different legislative obligations for data privacy.

Suggestions for Partiture Oy based on the research

Companies such as Partiture could take part in tackling the recognized challenges related to adopting new energy solutions in Finland, for example by acting as an integrator which connects various market parties in the Finnish electricity market. As an integrator, Partiture could offer services to both current and future market parties, to help them to practice their businesses more transparently. With visualization of household data and the collection and utilization of this data in various business processes, an integrator could help electricity market parties to recognize and develop their household related businesses and widen the overall understanding in a more understandable way. Making research about information flows among electricity market parties is a good start for creating transparency in business processes, increasing the trust between households and other electricity market parties and decrease concerns related to adapting new energy solutions in households.

Partiture and other similar service providers could decrease the concerns related to households’ data protection and privacy by evaluating their market parties and choosing to collaborate only with such energy companies and energy solution providers that are engaged to practice proper data protection and security methods. Partners also need to be transparent in what household data they utilize, how they have access to this data, and for which purposes they utilize it. In this way, an open discussion is created, and transparency could be improved. Partiture could support this open discussion and improve overall understanding in the Finnish electricity market by developing energy services which visually illustrate information flows in the Finnish electricity market. This way companies such as Partiture could promote open and transparent business in the future Finnish electricity market.

The limitations of the thesis

The observation of information flows was limited to discuss only about the flows that include relevant household data or utilization processes of this data. The choice of what data is relevant was made based on the literature review, interviews and consideration of the writer of this thesis. This is why all household data and information might not be discussed, and information flows might be different if the consideration of all the data collected from household would be examined.

This research included interviews with only for one case company. In order to make more comprehensive information flow illustrations and analysis about the information flow changes, interviews with other related market parties should have be made in the case studies. For example interview with solar inverter providers and representatives of Datahub could bring more precise information about household data and information collection and utilization purposes, which could then be illustrated in improved information flow figures. It should also be noticed that some of the illustrated information flows represent the situation in the future. For example, information flows related to

Datahub might be different from the one illustrated in Case study 3, as the Datahub system was still under development and not in use when writing this thesis.

Chapter 3 outlined every other market parties except ERs and DSOs from the consideration of electricity data metering and data transfer chain. Metering and transferring electricity data might involve also other market parties which were also not discussed in Chapter 3. To actually observe the responsibilities and roles of all the market parties who are related to electricity data metering and transfer, and analyze their responsibility for example in data security management, all the market parties should have been included in the research.

Suggestions for the future research

Future research could improve the visualization of information flows between future households and the new energy market parties to include more detail. Research could include more case studies, and interviews should be made also with new energy service providers, not only DSO and ER. This way more detailed information flow pictures could be made and examined on a more detailed level. Also, different case studies related to other energy solution than solar PV system and HEMS could be made, in order to achieve a more comprehensive understanding of household related information flows in the future Finnish electricity market. The selection of information flows illustrated could be widened in order to extend the scope of this research and make more comprehensive information flow illustrations.

Data security and privacy issues related to utilizing new energy solutions in the future households could also be made. The role of various market parties in ensuring consumer privacy and data security could be examined. Also the role of information flows in adaption of new energy solution could be studied more closely, in order to gain a better understanding of the possible challenges that utilization of new energy solution might bring.

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Legislation and recommendations relevant for this thesis

Electricity Market Act (Sähkömarkkinalaki 588/2013)

Energy Efficiency Act (Energiatehokkuuslaki 1429/2014)

Measuring Instruments Act (Mittauslaitelaki 707/2011)

Government decree on determination of electricity supply and metering, also known as Metering decree (Valtioneuvoston asetus sähköntoimitusten selvityksestä ja mittauksesta, tunnetaan myös Mittausasetuksena 66/2009)

Government decree on essential requirements of metering devices, demonstration of conformity and specific technical requirements (Valtioneuvoston asetus mittauslaitteiden olennaisista vaatimuksista, vaatimustenmukaisuuden osoittamisesta ja teknisistä erityisvaatimuksista 211/2012)

Government decree on changing the decree 66/2009 (Valtioneuvoston asetus sähköntoimitusten selvityksestä ja mittauksesta annetun valtioneuvoston asetuksen muuttamisesta 217/2016)

Decree of the Ministry of Employment and the Economy on data interchange related to the determination of electricity supply, also known as Message traffic decree (Työ- ja elinkeinoministeriön asetus sähkökaupassa ja sähköntoimitusten selvityksessä noudatettavasta tiedonvaihdosta, tunnetaan myös Sanomaliikenneasetuksena 273/2016)

Energy Authority’s regulation on itemization of bills concerning electric selling and electricity transmission (Energiaviraston määräys sähkön myyntiä ja sähkön jakelua koskevien laskujen erittelystä 1097/002/2013)

Principles of hourly metering 2016 & updated Finnish version from year 2016 (Tuntimittauksen periaatteita 2016)

Message Traffic Procedural Instructions, Practical Procedural Instructions for the Electricity Market (Sähkön vähittäismarkkinoiden menettelytapa- ja sanomaliikenneohje)

Ediel Messaging: General Application Instructions by the Finnish Energy Industries (Fingridin Ediel sanomavälityksen yleiset sovellusohjeet)